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Postgraduate Education in Engineering

THE last war, fought so largely on scientific lines, brought a general awareness of the drastic effects of scientific achievement on our daily life. On those concerned with the future livelihood of a Britain considerably depleted of its overseas assets, it impressed the importance of the less spectacular, but no less important, advances made possible by scientific development and the improvement of existing products. Not only the U.S.A., with their engineering background and large home markets, but also Switzerland, restricted and less favoured in natural resources than Britain, are competing successfully with British engineering goods.

Two difficulties in the way of more rapid scientific development in Great Britain are a sufficient supply of technologists highly trained in fundamentals and the application of technical sciences, and an urgent awareness of the importance of scientific development in all fields of engineering. The two are linked :—As scientifically trained men rise to high-level positions, they will strengthen scientific thought and, in turn, ask the educational institutions for personnel more highly trained in the pure and applied sciences related to their industrial fields. The movement, once started, will gather momentum ; its inception presents the greatest difficulties. In fact, the danger point is being reached now :—Educational opportunities are offered, but industry is reluctant or is not yet prepared to use them fully. Unless this situation changes, a retrograde development may take place in the near future.

Various plans for extending and improving technical education were discussed in Great Britain during the preparatory period between 1946 and 1951. The general public may remember the heated controversy as to whether a purely technical University of the continental and the Massachusetts Institute of Technology pattern should be established in Britain. However, more important than this question was the recurring observation that speed was essential and that a start had to be made as soon as possible on existing foundations, irrespective of future larger developments.

What are these foundations and how do they compare with those of the U.S.A. and, say, Switzerland ? There are the Technical Colleges leading to the Higher National Certificate, often nearly of first University degree standing, though the courses are more practical and specialised. The Universities give fundamental training (three years) with little specialist instruction. After graduation with the degree of B.Sc., the student has one or two years of workshop practice and, of necessity, a period of specialist training in the firm employing him. Post-graduate studies are nearly always devoted to research, leading to a higher degree (M.Sc. and Ph.D.).

The Universities in the U.S.A. combine the work of Technical College and University. Their first degree is sometimes equivalent to the Higher National Certificate. The actual training of highly qualified technologists is given in graduate departments by advanced instruction and, to a smaller extent, by mainly practical, industrially sponsored research. The entire training takes from four to six years. A preponderance of specialist technical courses in undergraduate work would not be acceptable to British Universities, nor would industrially sponsored research, since the Universities wish to keep their more fundamental outlook, and believe that both are more appropriate to Technical Colleges. The Swiss " Technische Hochschule " is entirely separate from the University, a system requiring duplication of fundamental training facilities and limiting desirable contacts between technical and other students. A year of workshop training is followed by five years of study, usually leading to a degree equivalent to a second British University degree (M.Sc.). It is argued that, as a result of the additional one to three years of specialist study, fully trained American and Swiss graduates have an advantage over British graduates in bringing a greater breadth of knowledge in their special field into industry and in not requiring the same initial training within their firms ; these advantages are, however, effective only if the firms are prepared to respect and to use the higher professional standing from the start.

Final recommendations to action crystallised in 1950. The Technical Colleges were encouraged to raise the level of their courses to first University degree standard, while maintaining their practical outlook, and to develop practical research facilities, so that their students would become more research-minded. This development is now in full progress ; several Colleges (e.g., Birmingham, Manchester, and Glasgow) have specialist courses and research facilities of high standing ; others will reach similar standing as their building programme advances.

The Universities were encouraged to institute postgraduate departments. This was no new departure : Imperial College already had a large programme of postgraduate teaching, leading to the D.I.C., a diploma of high postgraduate merit. Other Universities (e.g., Manchester) had regular postgraduate evening and part-time day courses in special subjects. The National Colleges (e.g., Cranfield for Aeronautics) provided full-time postgraduate training in selected industrial branches. Postgraduate research, leading to M.Sc. or Ph.D. degrees, was a regular and important feature of all Universities. The new proposals simply extended full-time postgraduate teaching in a more general range of subjects. In addition, at least two Universities are expected to develop their facilities to a full postgraduate institutional pattern similar to those of Massachusetts Institute of Technology or Zurich. According to a more recent decision, the Imperial College, London, will be one of these.

In recommending the extension of postgraduate training in some, and its inception in other, Universities, the Universities Grants Committee (U.G.C.) recognised that in the end the duration of technical studies would have to be extended by one or two years, but that industry would have to accustom itself gradually to the new, more highly trained personnel. A figure of 250 post-graduate students was therefore envisaged for a start, to be increased as demands and facilities grew. In contra-distinction to the existing part-time classes and National Colleges, the postgraduate departments were to teach full time on broadly conceived lines in the fields of civil engineering, mechanical engineering, electrical engineering, chemical engineering, metallurgy, mining, textiles, and agricultural engineering.

An important feature of the new postgraduate programme is its emphasis on advanced instruction

and set laboratory work, as against research, and on a small number of students in each department, so that individual tuition is possible and courses can even be adapted to individual wishes and requirements. It is designed to cater for graduates of the applied sciences, as well as Honours graduates in the pure sciences, who wish to equip themselves for special industrial work. Whereas pure-science graduates would normally go into research departments, it is felt that applied-science graduates would later be involved in production work and would therefore benefit from the experience gained by two or more years in industry before coming to the courses. Since engineering as a profession offers various opportunities for rising to high positions, the U.G.C. also recommended that men likely to benefit from the advanced instruction might be admitted, at the discretion of the Universities, even without a first University degree. The resulting combination, though testing the ingenuity of the teaching staff, would bring just that mixture of practical and fundamental scientific background which was desired. Moreover, it was hoped that the entry of students already in employment would associate industry more quickly and more closely with this new extension of University work, as well as with Universities in general, an association less cultivated in Britain than in many other countries. Funds for the maintenance of some of these older students were allocated by the Universities, but it was expected that firms sponsoring students would contribute.

Most of the postgraduate departments, therefore, do not provide a straight continuation of undergraduate studies, but serve two entirely different purposes, i.e., that of giving a specialist finish to wholly fundamental studies and that of offering a refresher and improving course to men returning from industry to the University. In this they are quite distinct from any other existing educational system. It remains to be seen, however, whether the two tasks can be combined successfully in one small department or whether a growing bias towards the one or the other side will make further specialisation necessary.

Research, although playing only a contributory role in postgraduate departments, is essential, and all departments are equipped with research facilities. Research students are working side by side with those receiving formal instruction. Even in these more specialised departments, research should be directed towards the fundamentals of the subject and should not deal with problems more suitable for firms' laboratories and trade research associations. In order to counter the attraction of a higher University degree in research, the Universities are recommended to grant suitable awards for successful attendance at the advanced classes.

The U.G.C. and other committees repeatedly emphasise in their recommendations that no uniformity should be imposed, but that the largest scope should be given to individual experiment and development in the organisation, equipment, and syllabus of these courses. Some postgraduate departments will quite naturally be attached to University departments known for their excellence in a particular field; others will be built up with regard to special local industries or to existing facilities in the University as a whole. Dispersal of postgraduate departments over the country will benefit an equally dispersed industry, and duplication of courses, therefore, need not be avoided at all costs.

The above programme outlined by the U.G.C. in 1950 has been implemented by the Universities. Postgraduate courses are being given at a number of these and have apparently worked to the satisfaction of the Universities and the students. All the newly instituted postgraduate departments have followed the lead given by the U.G.C. in recommending admission of qualified students from industry, even without a first University degree. The recommended figure of 250 has probably not yet quite been reached. Only a small minority of those attending are Honours graduates in pure science, wishing to specialise in industrial work. Most students are graduates and non-graduates with some industrial experience in government departments and abroad and in a small number of the very large firms. The response from industry in general has not fulfilled expectations, and this is also reflected in the number of students who come without being sponsored by their firms, or even after leaving them for the express purpose of attending the courses. It seems too early yet to appreciate the effect of the courses on those firms and government departments who have sponsored students.

The freedom of development recommended by the U.G.C. has been fully utilised by the Universities. Courses show the greatest variety, from the advanced instruction given in single subjects and fully integrated in the University curriculum, so that an outsider would hardly be aware of postgraduate activity, to the straight continuation of full-time instruction after the degree, or the entirely independent department devoted exclusively to postgraduate instruction and research.

Among the fully established, though not necessarily independent, departments, one might distinguish between those giving courses of at least one year and those with courses of only one year or less. Schools of the first type have planned their courses, so that an introductory instruction of one year leads students from other branches, or not fully qualified students to the degree standard in the special subjects chosen, whilst the second year gives the advanced lectures leading the student to the limits of knowledge in his subjects, a possible third year being allowed for independent research. Fully qualified students in such special subjects may omit the first year. Schools planning for shorter courses teach a limited number of selected subjects from the level of the general graduate to the most advanced. A few of these Schools, aware of the difficulties of industry in releasing a promising man for at least eight months at a time, have divided their courses by taking selected subjects successively and allowing students to attend for shorter periods dealing with one or two subjects only. The student may take different subjects in different years, or a firm may send members of its staff in a rota system to the various periods. Although students attending for only five weeks have expressed their general satisfaction with this arrangement, they have also indicated certain difficulties at the beginning of the course. It seems that attendance for at least two consecutive periods would help to minimise these difficulties, and the departments concerned therefore recommend such an extended attendance in the interests of the students.

Students often keep in touch with their firms and sometimes return to work during the academic intervals at Christmas and Easter, in order to attend to urgent business. This throws a heavy burden on the student, and not every student will be able to make full use of his studies under these conditions.

In spite of the (vaguely worded) recommendations of the U.G.C., most Universities are still not prepared to award a second degree without at least a minor thesis. A diploma is usually awarded for successful attendance of at least one year and for passing a final examination, but it is generally felt, that except for the D.I.C. of Imperial College, London, a diploma has not the same standing as a degree, especially as diplomas are also awarded for University courses much below the standard of graduation. As far as we know, no University except Leeds seems prepared to award an M.Sc. degree to a non-graduate, even if his postgraduate work is fully up to the required standard. Even Leeds requires full attendance for three years and an original research thesis, before the non-graduate can obtain his M.Sc. This attitude of the Universities must be viewed against the fact that some of them award the Master's degree to First-class Honours graduates without any further studies or research after a certain period of professional activity.

Since the postgraduate courses mainly follow the suggestions made by the U.G.C., only a few examples may be cited to show the diversity of postgraduate instruction:—The Imperial College, London, has postgraduate instruction in nearly all its departments and is well on the way to becoming a "Technische Hochschule." Although qualified persons from outside are admitted, these courses seem to appeal more as a direct extension of University education. In Manchester, postgraduate courses are fully integrated in the graduate departments, in which they deal with special aspects on an advanced level; they are often given with direct reference to local industries, and teachers are sometimes practising engineers in these industries. Attendance of only one or a few courses, as well as full-time attendance, is provided for. Edinburgh's School of Electronics and Radio is attached to a University department of international repute and uses the Ionospheric Research Station for field work. Leeds has a number of full-time departments giving the longer courses from one to three years (Fuel Technology, Gas Engineering, Chemical Engineering, Ceramics, Metallurgy, Textile Industry, and Mineral Dressing), each department

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U.S.A.

Magnetic Tape Recording and Reproducing of Television Signals

By H. F. Olson, W. D. Houghton, A. R. Morgan, J. Zenel, M. Artzt, J. G. Woodward, and J. T. Fischer. (From *RCA Review*, Vol. 15, No. 1, March 1954, pp. 3-17, 9 illustrations.)

A system for recording and reproducing television signals by means of magnetic tape has been developed. The elements of the system, which will handle both monochrome and colour pictures, are as follows:—

Tape and Tape-Transport Mechanism.

The tape used in this development consists of a cellulose acetate base coated with a red iron oxide. The acetate base is 0·0017 in. in thickness. The iron oxide coating varies among different makes from 0·0004 to 0·0007 in. in thickness. The width of the tape for colour television is 0·5 in. and that for monochrome television is 0·25 in. In the case of monochrome, 0·5-in. tape may be used with two parallel programmes on one tape. The coercive force of the tape used in the demonstration is 250 oersteds. The residual magnetisation is 770 gauss.

The tape-transport mechanism has been designed to limit any sudden speed changes to a very minute quantity and thereby to prevent "jitter" in the pictures. The order of constancy required can be illustrated by stating that a sudden speed change of one part in a million will put a jog of about 0·2 in. in the picture on a 12-inch kinescope. In addition, any slow drifts in speed have to be limited to considerably less than one picture element per scanning line.

The basic speed of the tape feed is determined by a capstan, driven at approximately 30 revolutions per second and having a circumference of one foot. Sudden changes in capstan speed are filtered out by a flywheel. Bearings on this capstan-flywheel assembly must be very smooth and perfectly aligned, and both static and dynamic balance of all parts must be accurate.

Even with accurate tape speed established by the capstan, tension in the tape supply and take-up must be held exact; otherwise, momentary changes in tape position will be introduced by stretch in the tape. Tension is maintained constant on the supply by driving a generator from the supply reel shaft, and using feedback to control the generator load to a constant tension load. The control must hold over a speed range of from 400 rpm (with a full reel) to over 860 rpm (when the reel is empty).

The take-up reel is motor-driven and has its feedback circuit arranged so that a constant tension on pull-out is obtained. Both supply and take-up tensions are held constant, whether the reels are empty or full.

A diagram of the complete transport mechanism is shown in Fig. 1. Four fixed idler pulleys (2), (4), (9), and (12) are used to guide the tape from the supply reel (1) over the heads (5), (6), (7), and (8) and the capstan (10), and onto the take-up reel (13). A rubber-surfaced idler (11) is sprung against the capstan to act as a depressor in holding the tape on the capstan for speed determination.

The tape reels are an important part of the tape-transport mechanism. The reel must not have excessive inertia if a practical starting time is to be achieved, and must be accurately balanced if full advantage is to be derived from the constant-tension reel drives.

The playing time of a full reel of tape is dependent on the diameter of the reel, the thickness of the tape, and the speed of the tape. The present reels used are 17 in. in diameter and have a hub 8 in. in diameter. The present tape is 0·0021 in. in thickness. A full reel contains approximately 7000 ft of tape. This length of 0·5-in. tape weighs 4·3 lb and will play approximately 4 minutes at 30 feet per second. An objective of current research is to handle 15 minutes of programme time, using reels of 19 in. in diameter. A fifteen-minute reel could be considered a unit reel for television programmes. Longer shows would be handled by using two reproducers alternately, as is usual in motion-picture theatre presentations.

Recording and Reproducing Heads

The difficulty of the problem of recording video signals on magnetic tape is obvious. Application of the techniques employed for recording sound on tape seems almost futile when the demands of video recording are enumerated. To be more specific, a frequency of 4 megacycles per second recorded on a tape travelling at 30 feet per second results in a wavelength, on the tape, of less than 0·0001 in. Quite obviously, the effective gap length of the recording and reproducing heads must be considerably less than the wavelength to be recorded, and the problem of producing heads with exceedingly small effective gap lengths must be accepted.

Furthermore, the fact that the head gaps must be straight, if the tape is to be recorded on one head and reproduced on another head without loss of over-all performance, must be considered.

The electrical and magnetic performance of the heads is all the more formidable, for the reason that some 16 to 18 octaves of frequency range must be covered. The magnetic path of the heads must be made of a material which will maintain a high permeability over the entire frequency range. The coil surrounding the magnetic path of the head must produce a reasonable electrical impedance over the frequency range, and it is particularly important that the electrical impedance be free of resonances in the higher frequency range.

The physical configuration of the heads must satisfy a number of conditions. Firstly, the assembled head

must be stable with time against such adverse conditions as temperature and humidity cycles. Secondly, the head must have good wear resistance to the abrasive effect of the passage of the tape. Thirdly, the head must be physically small to allow for the grouping of multiple channels, such as in the colour recording and reproducing procedures. Finally, there are numerous other mechanical requirements, such as mounting of the heads, shielding of the electrical connections, head-position adjustments, etc.

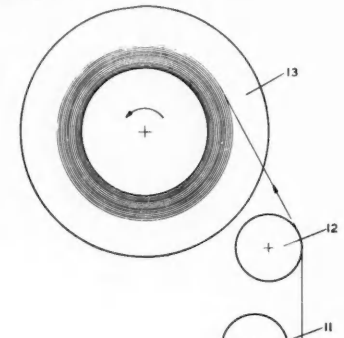

Fig. 1. **Schematic layout of tape-transport mechanism.**

Difficult as the above requirements may be, it has been found possible to develop a set of heads providing a reasonable solution to all these problems. The present arrangement of the head assembly for recording the colour video signals on tape is shown in Fig. 1. The left-hand head (5) is for recording the sound. The central head (6) is the video-recording head, which is made up of four elemental heads to provide four channels. The right-hand head (7) is the video-reproducing head, which also contains four elemental heads. The sound-reproducing head (8) is placed at a point following the tape-drive capstan (10), for the sake of expediency only. In a final design, both video and sound heads would probably be incorporated in a single unit. It may be noted that the sound-recording head is positioned so that the sound track is centred between two of the video tracks.

Tests have established that the frequency response of the heads is uniform, with a reasonable signal-to-noise ratio up to approximately 3·5 megacycles per second. The impedance of the elemental head is substantially free of resonances to the highest frequency. The wear properties of the heads, although not completely examined, have been satisfactory.

The erase head (3) is a specially designed permanent magnet, which subjects the individual elements of the tape to reversing magnetic fields and leaves the tape in a fixed magnetic condition. This head is physically removed from the tape path when the erasing operation is not desired.

Audio System

In conventional magnetic tape recording systems used for audio frequency work, the tape usually moves past the recording and reproducing heads at a speed in the neighbourhood of 1·25 feet per second. With such systems, careful design and adjustments are necessary for success in recording and reproducing the higher audio frequencies, say, above 10,000 cycles, because of the extremely short wave lengths of these higher frequencies. In the video tape-recording system, where the tape speed is 30 feet per second, the situation with respect to recording audio frequencies is reversed. It is now more difficult to record and reproduce the lower audio frequencies at useful levels above noise because of the extremely long wave lengths of the lower frequencies. For example, a 100-cycle tone recorded by the video tape system has a wave length of nearly 4 in., while the same tone recorded on a conventional audio tape recorder has a wave length of only 0·1 in. or less.

A consideration of the problem of recording and reproducing the lower audio frequencies, together with the requirement of a complete absence of cross-talk between the audio track and the adjacent video tracks recorded on the tape, has led to the use of a modulated-carrier method of recording the audio signals in the present system. Thus, the audio frequencies are not recorded directly on the tape; instead, a high-frequency carrier signal is recorded, and this carrier is amplitude-modulated by the audio-frequency signals. Upon playback from the tape, the modulated carrier is amplified and demodulated to give the reproduced audio signals.

The frequency of the carrier is 150 kilocycles. The recording and reproducing amplifiers both employ tuned circuits, with a pass band centred at the carrier frequency. The audio recording and reproducing heads are essentially the same as those used in the video channels. A switching arrangement can be used to connect the audio amplifier input directly to the audio input of the modulator. This permits listening to the audio programme without first passing the signal through the tape system.

Video System for Colour

The composite colour video is coupled to a colour demodulator which produces, on separate outputs, the three colour video signals (red, green, and blue), and the separate synchronising components. The four signals thus obtained are coupled to their respective recording heads through four recording amplifier units.

The sound or audio signal, which may be obtained from the audio output of a television receiver, is coupled to the audio-recording head through a fifth recording amplifier unit, as previously described. The recording amplifier units provide both phase and frequency compensation, in order to obtain the desired flux pattern on the tape. The signals are recorded on five separate tracks on the magnetic tape. There is one track for each of the primary colour video components (red, green, and blue), one for the associated synchronising information, and one for the audio or sound signal.

As the tape travels in an upward direction, the erase head first removes all previous information from the tape and conditions the tape for recording. The tape then travels past the recording heads, where new information is impressed. The information is stored on the

tape in the form of a flux pattern, which corresponds to the signal. The energised tape then travels past the five reproducing heads, which are used for reproducing or monitoring purposes. The reproducing heads generate electrical signals corresponding to the flux patterns stored on the tape. Since the reproducing heads do not change the flux pattern on the tape, any desired number of reproductions may be obtained by merely running the tape through the machine, with the erase and recording heads de-energised. In order to de-energise the recording heads, an on-off switch, which permits the removal of all signals from these units, is provided.

Each of the recording amplifiers contains a special biasing unit. This unit applies an appropriate signal to the tape, so that the full magnetic amplitude range may be used for the video signal. In other words, the "black" level of the video wave is made to occupy a particular value on the magnetic characteristic of the tape. The "white" signal components then vary the magnetic pattern relative to this value.

The output signals from the magnetic tape are essentially in the form of the output signals from a television colour camera. To use these signals to modulate a television transmitter, it is necessary to form a composite signal, just as is done with camera signals at a studio. One difference exists in the use of magnetic-tape output, for here the synchronising signals are reconstituted and related to the information recorded on the tape.

Video System for Monochrome

When black-and-white television signals are to be recorded on magnetic tape, only two tracks on a 0·25-in. tape are required, one track being used to carry the complete video signal and the other for the associated audio signal.

The video signal is coupled to the video-recording head by means of a recording amplifier. This amplifier inserts the required phase and frequency compensation, to permit the desired flux pattern to be formed on the tape. The audio signal is coupled to the audio-recording head by means of an audio-recording amplifier. The audio system consists of a carrier generator, modulator, and amplifier, as already described.

As in the case of colour, any previously recorded information is removed from the tape by a specially designed permanent-magnet erase and conditioning head. The tape then travels past the recording heads and on to the reproducing heads. The recording heads record the video and sound signals on the tape in the form of a flux pattern which corresponds to the signal, as described for the colour system.

The reproducing heads generate a signal which corresponds to the flux pattern on the tape. The video signal, generated by the video-recording head, is coupled to a video-reproducing amplifier, where amplitude and phase correction are applied. The output from the reproducing amplifier is the complete video signal, which may be applied to a television transmitter.

Demonstrations

For the purpose of demonstrating the system, all programme material originated in a television studio in New York. The picture was picked up by means of a colour-television camera. The output of the camera was fed to standard studio-type video equipment, to produce a composite video colour signal. The output of the microphone was fed to standard studio-type audio equipment. The audio signal was carried by a telephone line from New York to Princeton. The composite video signal was carried by microwave radio relay from New York to Princeton. The audio signal was fed to the modulator of the recording equipment. The composite colour video signal was demodulated into the red, blue, and green video signals and the synchronising signal by means of a colour demodulator. These signals were sent to the input of the recording system. The outputs of the synchronising red, blue, and green video-recording amplifiers and the sound modulator were fed to the recording heads. In reproducing, the outputs of the reproducing heads were fed to the synchronising red, blue, and green video amplifiers and the sound demodulator. The outputs of the amplifiers correspond to the direct red, blue, and green video signals and the audio signal. The direct signals and the reproduced signals were fed to a switch gear. The output of the switch gear was fed to two colour-television receivers. Each of the colour receivers was equipped with a tri-colour kinescope for the reproduction of the picture, and with a loudspeaker for the reproduction of the sound. By means of the switch gear, it was possible to switch both receivers to the direct signals, or both receivers to the reproduced signals, or one to the direct signal and one to the reproduced signal.

Four similar demonstrations were given, in which the following programme was presented :—

(1) The reproduction of a magnetic tape recording of a monochrome television signal containing an introductory message by an actress. The tape was recorded several days before the demonstration.
(2) The reproduction of a magnetic tape recording of a colour television signal containing a Christmas sketch by the same actress. The tape was recorded several days before the demonstration.
(3) The reproduction of a magnetic tape recording of a monochrome television signal containing a Victorian sketch by the actress. The tape was recorded several days before the demonstration.
(4) In this part of the demonstration, a live programme from the studio, consisting of a Victorian sketch by the actress, was fed by a microwave radio relay to both receivers. Half-way through the sketch, one receiver was switched to the signal reproduced by the magnetic tape, so that a comparison could be made of the direct and reproduced pictures. The delay introduced between the direct and reproduced pictures was the time required for the tape to travel from the recording to the reproducing head. Since this is only 4 milliseconds, the delay was imperceptible. This test demonstrated the fidelity of the reproducing system.
(5) The tape recorded in (4) was rewound and played back.

Conclusions

In a complex operation such as video recording, it is difficult to derive a figure of merit which will permit an objective evaluation of the system. The opinions of a sufficiently large number of observers, however, give a good indication of the success of the system. The demonstrations described above were shown to several hundred members of the press, industry, and other diverse interests. The magnetically reproduced monochrome and colour pictures were considered to be very nearly as good as the pictures received by direct transmission.

In addition to the quality of pictures, the magnetic system has two other notable advantages over the more conventional film recording. These are reduced costs and the fact that instantaneous playback is possible. It has been estimated that the cost of recording a monochrome programme on tape will be about 10% of what it would cost to record the same programme on film. The corresponding figure for a colour programme would be about 5%. This difference in cost is due in part to the fact that the tape may be erased and re-used a great number of times.

In kinescope film recording, it is necessary to process the film before the recorded pictures can be viewed. This usually requires several hours. The instantaneous playback feature of the tape system permits simultaneous recording and monitoring of the recorded picture. The advantages of such a feature are self-evident.

GERMANY

Investigation of the Rupturing Processes in Plastics

By H. SCHARDIN. (From *Kunststoffe*, Vol. 44, No. 2, February 1954, pp. 48-55, 22 illustrations.)

In the following article a series of high-speed cinematographic recordings of the rupturing processes in plastics is reproduced and discussed, and the information which may be derived from the appearance of the fracture surface is assessed. Finally, an account is given of the processes involved in the bursting of plastic foils, for the investigation of which high-speed cinematographic methods alone have so far been found applicable.

WHEN a crystalline material is subjected to a tensile test, a reduction in the cross-sectional area first occurs, owing to molecular slip in which the molecules find new positions of equilibrium without, however, losing their coherence. Only after the material has been subjected to such a degree of deformation that additional stresses will no longer lead to new positions of equilibrium will it tear apart. The latter process commences with a stage in which the speed of rupture, starting from very small values, will generally increase very rapidly to high values, so that direct observation can be effected only by means of high-speed cinematography, operating at 100,000 or more frames per second. In the case of plastic materials, conditions are similar. When the stress is increased slowly, the deformation taking place is caused by a change in structure, although the latter phenomenon is more complex than the corresponding processes in crystals.

High-frequency cinematographic recordings of rupturing processes in plastics have occasionally been made in the past, particularly in the case of very high stresses, such as those occurring from the detonation of an explosive or the impact of a bullet, and also in the case of stresses which increase during a very short period only, and which are caused, for instance, by a falling weight.

It was considered desirable to supplement these experiments by others, in which the loading of the specimen would increase relatively slowly. For this purpose, plates made of Plexiglass were clamped in a tensile-test machine and subjected to a gradually increasing tensile stress whose rate of increase could be regulated as required. The cinematographic recording was effected by a multiple-spark camera, as indicated in Fig. 1, in which 24 sparks (of which only 4 are shown)

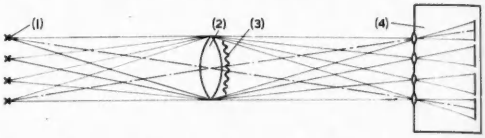

Fig. 1. **Schematic arrangement of high-speed cinematographic recorder.**

(1) Spark gaps. (2) Condenser. In practice, this is usually replaced by a concave mirror. (3) Testpiece. (4) Camera with four lenses. The arrangement used in the experiments was designed to produce 24 pictures.

are produced successively at controllable time intervals (of the order of 10^{-5} sec between successive sparks). A separate lens is provided for each spark, and the images of the 24 successive sparks are recorded on a single photographic plate of 18 × 24 cm. For triggering the 24 sparks exactly at the onset of the fracture, the following arrangement was designed:—The specimen was notched on one side only, so as to locate the point of inception of the fracture. A strip of aluminium was then vapour-deposited on the surface of the plate and connected with an electric circuit. When the aluminium breaks, the first spark is triggered, followed automatic-

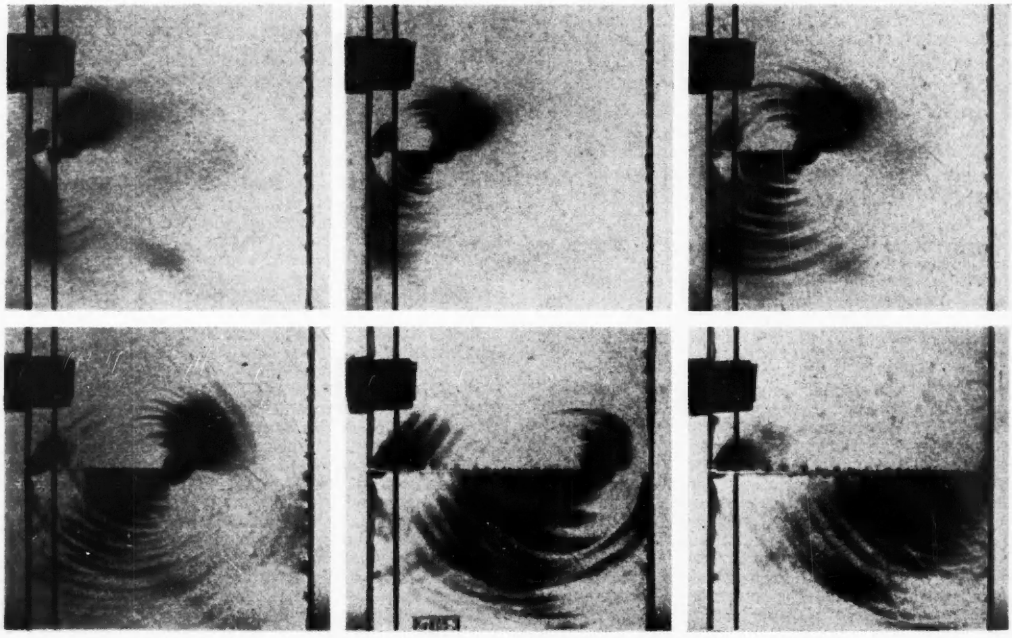

Fig. 2. **Six of a series of Schlieren photographs of the rupturing of a Plexiglass plate.**

Recording speed, 130,000 frames per second; maximum speed of rupture, 605 m/sec; duration of load application, 124 sec; rounded notch, 1 mm in width, 3 mm in depth; dimensions of plate, 200 × 100 × 8 mm.

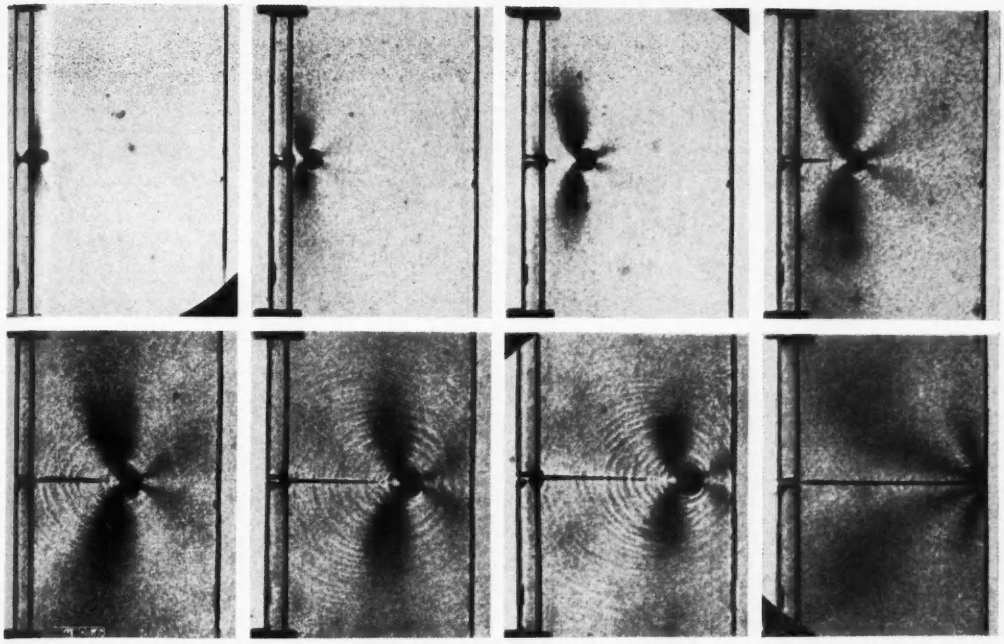

Fig. 3. **Eight of a series of stress-optical patterns of the rupturing of a Plexiglass plate.**
Recording speed, 126,000 frames per second; maximum speed of rupture, 515 m/sec; duration of load application, 74 sec; saw-cut notch, 2 mm in width, 10 mm in depth; dimensions of plate, 200 × 100 × 8 mm.

ally by the remaining sparks at predetermined intervals. To record not only the rupture but also the accompanying stresses, both Schlieren and stress-optical methods were used. Fig. 2 shows a series of Schlieren photographs, in which the pattern and the intensity of the dark and light areas vary with progressive rupture. In this connection, the following observations can be made :—

(1) Immediately ahead of the front of the fracture, and travelling with it, is a black spot resulting from the transmitted light being deflected to such a degree that it no longer reaches the optical system. This is caused by the stress concentration ahead of the front of the fracture.

(2) In the field ahead of the fracture, the upper half is dark, whilst behind the front of the fracture, i.e., on both sides of the already fractured material, the lower half is dark. This can be explained as follows :—When the plate is subjected to tension, it not only stretches but its thickness is reduced. However, when the fracture progresses, a corresponding stress relief takes place and the plate is restored to its original thickness. This sudden alteration in thickness produces a deflection of light, similar to that in a prism, and this is of opposite direction in the upper and lower sections. Ahead of the front of the fracture, the conditions are reversed. The stress relief, and hence also the thickening of the plate, travel ahead of the actual fracture, as the velocities of the longitudinal and transverse waves exceed that of the progress of the fracture. The change in thickness will be smallest in the middle, so that, ahead of the front of the fracture, the prismatic deformations of the plate will be in a reverse position to those behind that front. In consequence, the distribution of illumination is such that the plate is dark in the upper section and light in the lower section.

(3) The travelling elastic waves are also visible. It can be shown that they originate in the front of the fracture. They become visible owing to irregularities in the path of the fracture.

Fig. 3 shows a series of stress-optical patterns of a rupture test. Here, luminosity distribution is symmetrical. These patterns show a very distinct dark area ahead of the front of the fracture, caused by the stress in this part. The travelling elastic waves are also clearly visible. The stress pattern permits, in principle, the evaluation of the stress distribution.

Photographs, such as those shown in Figs. 2 and 3, enable a quantitative determination to be made of the speed of the various phenomena from the intervals between the sparks, which, by means of a rotating drum, can be measured with an error of the order of only 10^{-8} sec. Evaluation of one series of tests showed, for instance, that, during the first stage of rupture, i.e., during the first 50 microseconds, the speed of rupture was 374 m/sec, and during the remaining stages, i.e., until complete separation, it was 515 m/sec. A time check, obtained by vapour deposition of four more aluminium strips and the use of an electronic counter, showed complete agreement with the original results. An additional check with regard to the exact position of the front of the rupture can be made from the origin of the travelling waves. Measurements on a large number of specimens showed that the speed of rupture of the type of Plexiglass tested ranged between 500 and 700 m/sec, and that it depended on the static load at the moment of final separation.

The rupture shown in Fig. 4, and evaluated in Fig. 5, initiates at a constant speed of 655 m/sec. The first photographs show a strong wave formation, due to irregularities in the formation of the rupture. The third picture shows the onset of branching of the hitherto simple path; both paths, however, progress at the same speed. Somewhat later, a new rupture occurs between the two existing paths and the speed of propagation of the lower path falls at the same time to 450

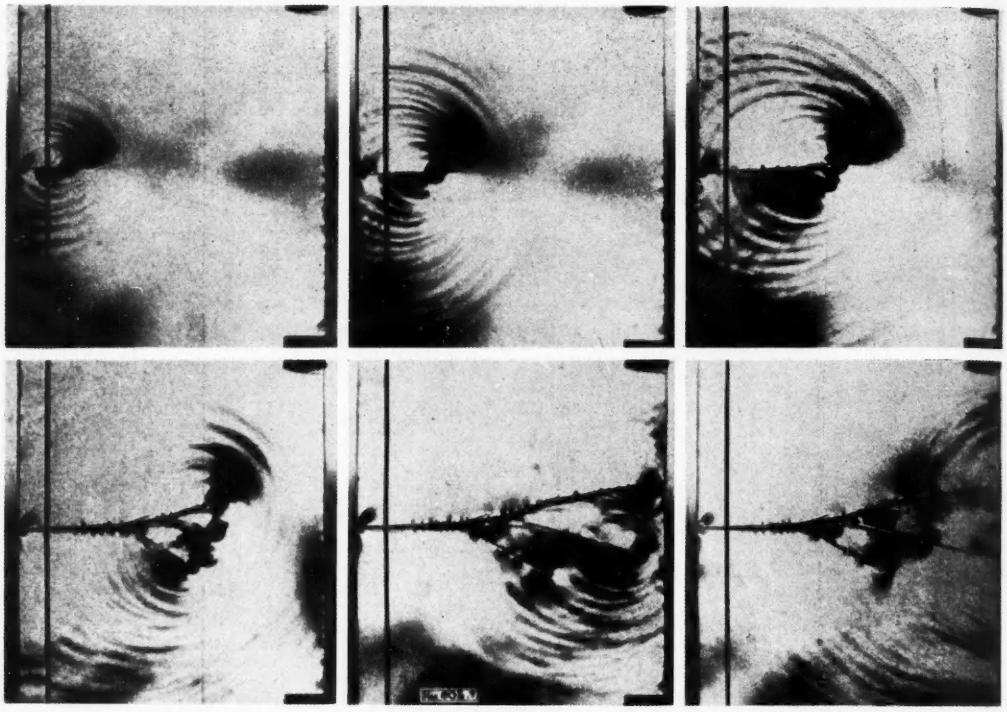

Fig. 4. **Six of a series of Schlieren photographs of the rupturing of a Plexiglass plate, showing branching of rupture paths.** Duration of load application, 107 sec; rounded notch, 1 mm in width, 1·5 mm in depth; dimensions of plate, 250 × 100·8 × 4 mm.

m/sec. The speed of propagation of the upper and middle fractures remains unchanged until the end. As a result, the following conclusions may be drawn :—As mentioned previously, the formation of a rupture leads to stress relief in its vicinity; it may therefore be expected that, on branching, the two branches to some extent mutually reduce their respective stresses. If the speed of propagation were a function of the stress, multiple fractures would propagate at a lower velocity than would simple fractures under identical initial conditions. The photographs show, however, that multiple fractures may travel at the same speed as simple fractures, although they can also reduce their speed suddenly or even stop altogether. It may therefore be said that the speed of rupture depends on the strain, but not on the stress, of the specimen. If sufficient time is available, the elastic stress will produce the corresponding strain, i.e., the corresponding structural changes. If this is not the case, the strain, and not the stress, will determine the speed of propagation of the rupture. If the stress is no longer sufficient to supply the energy required for the continuation of the fracture, the speed will drop to a lower value or the fracture will discontinue completely.

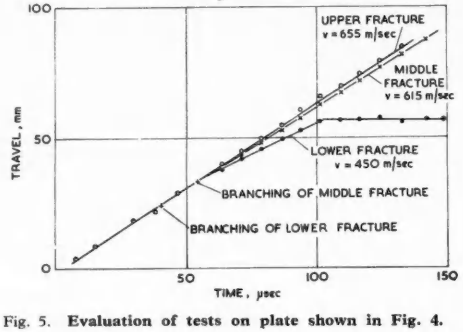

Fig. 5. **Evaluation of tests on plate shown in Fig. 4.**

PHENOMENA AFTER COMPLETE SEPARATION OF THE PLATE.

Figs. 6 and 7 show Schlieren photographs and stress-optical patterns of a plate during, as well as after the completion of, rupture. In particular, in the fifth of the stress-optical patterns, representing the instant of completion of the separation, no locked-up stresses appear to remain in the plate. As this, however, is concentrated ahead of the fracture, it is now travelling in the reverse direction in the plate. This can be seen from the Schlieren photographs and in the last three of the stress-optical patterns. A point of particular interest is the front of the transverse wave which travels along the rear edge of the plate in an upward and downward direction. Only behind this front can lateral relief take effect, and this takes place with considerable intensity. When the fracture reaches the boundary, a wave is set up in the surrounding air, starting from the front of the transverse wave; this is the wave impulse which produces the audible crack of a rupture process.

On examining the fracture surface of Plexiglass plates with the naked eye it will be seen that it appears highly polished at the origin of the fracture, and that it becomes progressively rougher. This roughness is connected with the speed of propagation of the rupture and hence with the stress at the instant of final separation. In consequence, the higher the speed the larger is the polished surface. On the other hand, the degree of

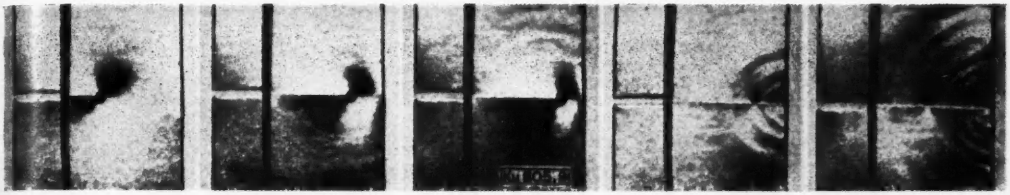

Fig. 6. **Five of a series of Schlieren photographs of the rupturing of a Plexiglass plate.**
The fourth and fifth photographs show phases of the plate after complete separation.

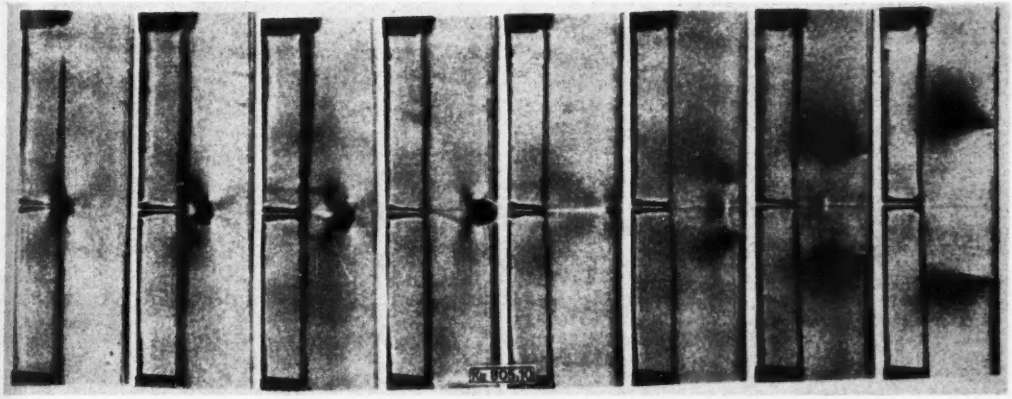

Fig. 7. **Eight of a series of stress-optical patterns of a Plexiglass plate.**
The fifth photograph shows the plate at the moment of final separation ; the sixth, seventh, and eighth photographs show the development of internal stresses after separation.

roughness is no indication of the absolute speed of propagation, as to some extent it also depends on the pre-stressing.

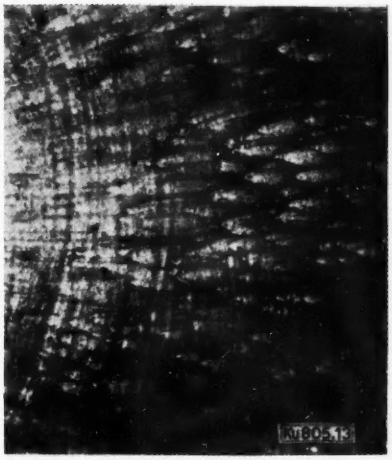

Fig. 8. **Photomicrograph (× 20) of the cross-section of fracture in the transition zone between smooth and rough zones.**

Fig. 8 shows a photomicrograph (× 20) of the fracture surface at its transition from the mirror to the rough section. It will be seen that the rough portion is characterised by a large number of closely packed hyperbolas. These are caused by a secondary fracture preceding the main fracture. The secondary fractures originate in individual points from which they radiate in circles. Their plane does not coincide with that of the main fracture and the hyperbolas represent the lines of intersection of both. After separation, the surfaces no longer match each other exactly ; where the fronts of

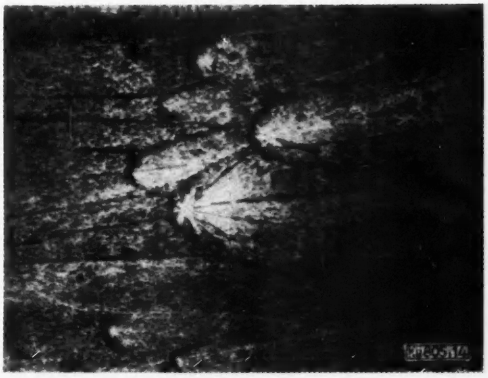

Fig. 9. **Part of Fig. 8 under higher magnification (× 135).**

the fractures intersect, the material is subjected to plastic deformation, a process which is typical of plastics and does not occur, for instance, in the case of glass. Fig. 9 shows the fracture hyperbolas under greater magnification (× 135). In areas of considerable roughness, the secondary fractures overlap to a very marked degree.

Measurement of Speed of Rupture Propagation by means of Wallner-Lines.

In 1939, Smekal found a method of measuring the speed of rupture propagation by means of the so-called Wallner-lines. Where the main fracture runs along the surface of the plate, it causes the internal stresses, always present on account of surface roughness, to be relieved.

This leads to transverse waves emanating from points with particularly strong indentations, which, coinciding with the travelling fracture, slightly deflect the latter from its original direction. The resulting curves permit the relative speeds of the rupture and the transverse waves to be determined.

Time-marking of a Fracture Surface by Ultrasonic Waves.

Time-marking of the fracture surface for the qualitative evaluation of rupture tests can be effected with the aid of ultrasonic waves by the arrangement shown dia-

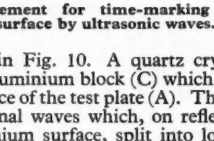

Fig. 10. **Arrangement for time-marking of a fracture surface by ultrasonic waves.**

grammatically in Fig. 10. A quartz crystal (B) is cemented to an aluminium block (C) which in turn is fixed to the rear surface of the test plate (A). The quartz crystal emits longitudinal waves which, on reflection from the inclined aluminium surface, split into longitudinal and transverse components, whose relative magnitudes depend on the angle of the reflecting plane. As transverse waves only are required for timing, the angle is chosen so as to give complete transformation of the incident energy into transverse waves. If a transverse wave is made to travel in an opposite direction to that of the progressing fracture, the path of the latter is periodically deflected and it is possible, from the distances between the individual deflections and the oscillation frequency of the crystal, to calculate directly the speed of rupture.

Cinematographic Investigation of the Bursting Process.

Fig. 11 shows the arrangement used for the investigation of the bursting process in plastic foils. The back of the pressure chamber is formed by a glass plate (C),

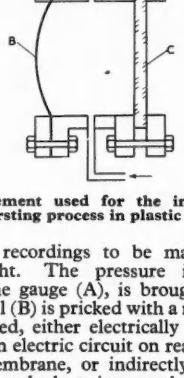

Fig. 11. **Arrangement used for the investigation of the bursting process in plastic foils.**

which permits recordings to be made by means of transmitted light. The pressure in the chamber, registered on the gauge (A), is brought to the desired value and the foil (B) is pricked with a needle. The spark release is initiated, either electrically by the advancing needle closing an electric circuit on reaching a metal foil fixed to the membrane, or indirectly by the pressure wave produced by the bursting membrane. Figs. 12 and

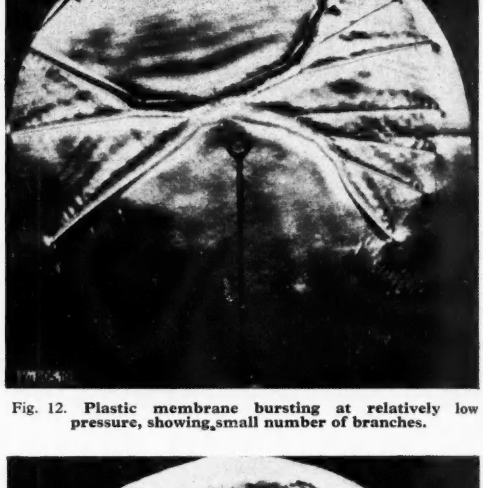

Fig. 12. **Plastic membrane bursting at relatively low pressure, showing small number of branches.**

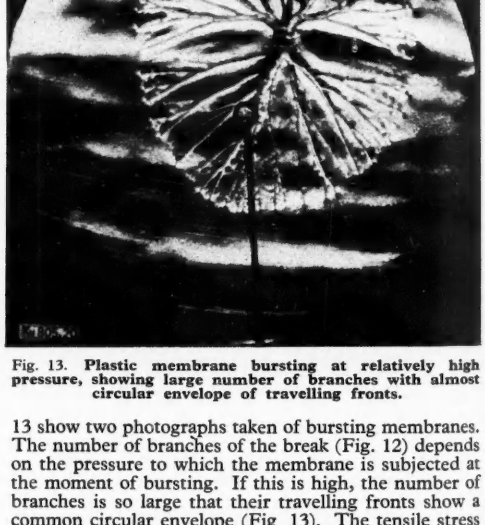

Fig. 13. **Plastic membrane bursting at relatively high pressure, showing large number of branches with almost circular envelope of travelling fronts.**

13 show two photographs taken of bursting membranes. The number of branches of the break (Fig. 12) depends on the pressure to which the membrane is subjected at the moment of bursting. If this is high, the number of branches is so large that their travelling fronts show a common circular envelope (Fig 13). The tensile stress of the membrane affects not only the number of branches, but also the bursting speed. Whilst the speed of bursting is a function of the tension of the membrane, it can be shown that it is not affected by its thickness.

Also of interest are the results of measurements on unidirectionally stretched foils. Such foils have a higher resistance in the direction of the stretching. At right angles to this direction, however, the resistance is less than in an unstretched foil. The foil therefore bursts in the direction of the lowest resistance. With increased stretching, the number of branches of the break decreases, until only one path remains.

Forced-Torque Electric Adjustable-Speed Drives

By V. R. MURPHY. (From *Product Engineering*, Vol. 25, No. 4, April 1954, pp. 168-172, 6 illustrations.)

By increasing the rate of acceleration and braking, and by permitting rapid speed variation during a cycle, forced-torque machine drives have increased production, decreased spoilage of material, and reduced maintenance. This article gives indications as to whether this type of drive can improve the performance of a particular machine and, if so, by how much.

THROUGH the application of a new type of electric motor drive and control system, the production rates of certain kinds of machines can be increased. This is achieved by faster motor acceleration and braking, and by automatic speed changing. By this means, each step in a series of machine operations can be performed at the highest permissible speed. If one portion of an operation permits a significantly higher speed than another, the operation can be split into portions, each running at its highest practical speed.

Change of speed is so rapid that it is often possible to drive the machine at a number of successive speeds, each of short duration and of widely different magnitude. For example, the time required for the motor to go from rest to a full speed of 750 rpm is of the order of a half a second. This often makes it desirable to change speed, even though the running time at the changed speed may be relatively brief compared with total cycle time.

Indicative of the results that can be achieved, this new drive and control system was applied to a 500-hp motor driving a triple-action press for forming parts of automobile bodies. During operation for more than two years, production rate was increased and down-time for repairs was reduced. The increased production rate resulted from two factors: A 50% decrease in scrap (from 10 to 5% of total production because of speed changing and improved speed control during the working portion of the cycle), and speed changing to higher speeds during non-working portions of the cycle, causing a shorter total cycle time. Comparable results have been obtained on other machines, e.g., planers, automatic conveyors, and press feeders. It should, however, be understood that this type of drive is not confined to high horsepowers only.

A characteristic of the drive is that the motor is directly coupled to the main drive shaft, so that a brake, clutch, and very often a flywheel, are not required. Braking and speed control are effected electrically, with no wear and with minimum shock. However, some machines must be equipped with a small brake to hold a certain stationary position, for example, when mounting dies in a press.

Adjustable motor speed is obtained by the Ward-Leonard principle, in which the driving motor is d.c., with its shunt field across a separate voltage supply. The armature of the shunt-wound d.c. motor is across an adjustable voltage constant-speed d.c. generator. Varying the output voltage of the d.c. generator by field control changes the speed of the d.c. driving motor.

The rate of acceleration of the driving motor from one speed to another depends largely on how rapidly the generator voltage can be made to build up. In Fig. 1 is shown the time-voltage curve of a typical generator under normal starting conditions and under the condition of "forcing," wherein approximately eight times normal field voltage is instantaneously applied. When the generator output voltage reaches its normal level, regulator action immediately reduces the high field voltage to the proper value. Thus, the forcing action reduces the time required to reach the operating point.

The intensified "starting" voltage is called the forcing voltage. Usually, it is four to eight times the normal running voltage. In this forced-torque system, the forcing voltage is applied automatically whenever the controls call for increased motor speed. The electrical system is so designed that it automatically and accurately controls the voltage across the motor, so as to obtain maximum permissible accelerations and yet avoid electrical damage or undesirable mechanical shock. The "secret" of the whole system is the attainment of the voltage changes almost instantaneously.

Changes to lower speeds are obtained by regenerative braking. This is not only much more rapid than mechanical braking, but is more accurately controllable and does not get out of adjustment.

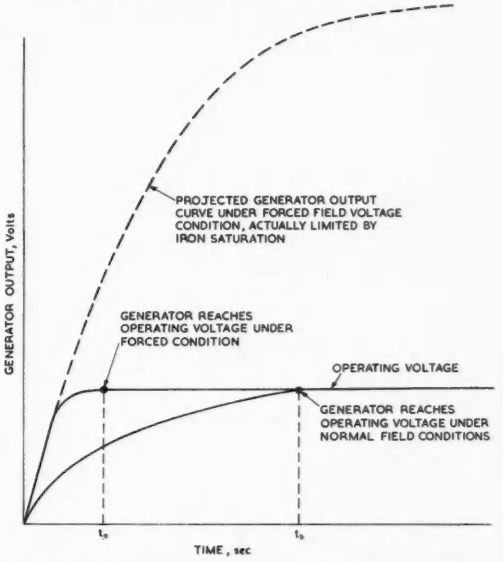
GENERATOR OUTPUT, Volts
PROJECTED GENERATOR OUTPUT CURVE UNDER FORCED FIELD VOLTAGE CONDITION, ACTUALLY LIMITED BY IRON SATURATION
GENERATOR REACHES OPERATING VOLTAGE UNDER FORCED CONDITION
OPERATING VOLTAGE
GENERATOR REACHES OPERATING VOLTAGE UNDER NORMAL FIELD CONDITIONS
t_a
t_b
TIME, sec

Fig. 1. **Time-voltage curves for generator under normal and forced field conditions.**

With high field voltage the generator output follows the projected curve until just before the generator voltage reaches its normal value. At this point regulator action takes place and the field voltage is reduced to normal. Thus, the operating voltage is reached in time t_a. With normal field voltage, generator output does not reach the operating voltage until time t_b. A rapid rise in generator voltage causes a rapid increase in motor torque and acceleration, allowing fast speed changing.

As is to be expected, a forced-drive system costs considerably more than a conventional a.c. motor and control. Therefore, before incurring the expense of detailing the engineering application of the system, a study should be made to determine the increased production possible and other savings obtainable. The results of such a study will show whether or not it would be profitable to apply the system.

In the operation of every machine, the total time required for the completion of a cycle of operation will be the sum of the time consumed for each of the following steps of the cycle:—

(1) The time required to accelerate the motor from zero to the balanced running speed of the first operation.
(2) The balanced-speed running time during the first operation.
(3) The time required to change the speed from that of the first operation to that of the second operation.
(4) The balanced-speed running time for the second operation.
(5) The time consumed for successive speed changes

and balanced-speed running, including speed reversals, as stated in (3) and (4).

(6) The time required for stopping the machine.

In certain machines there will be only starting, running, and stopping. In others, the series of operations performed and the number of different speeds desired may be numerous. Many machines, as now driven, perform certain successive operations at the same speed, although some of the operations could be performed at a much higher speed. A single running speed might be used, because, with a conventional drive, it would be impractical or impossible to change the speed rapidly enough for successive operations. The simple crank-type draw press with a conventional motor drive is an example. In the operation of such a press the slowest required speed is that when the descending die is about to touch the sheet. The speed can then be increased somewhat to the end of the down stroke and further increased when the die begins to withdraw. Then, the balance of the return stroke and the first part of the down stroke can be at high speed. To attempt to obtain this optimum-speed cycle by mechanical means would be impractical. Consequently, in conventional press drives the running speed is determined by the slowest speed required in the cycle of operations.

Whatever the machine may be, the first step in the analysis is to make a time-speed curve, to determine whether or not the forced-torque drive system may show substantial savings.

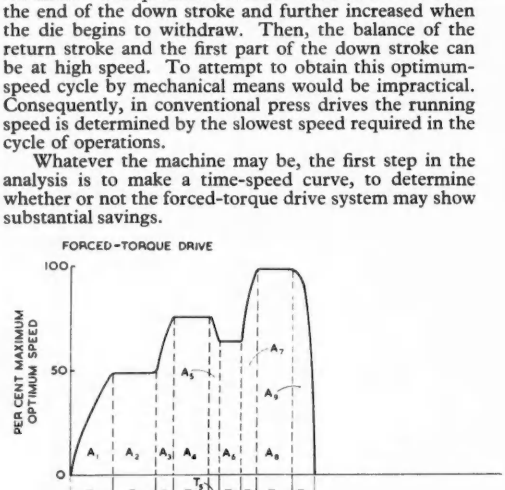

Fig. 2. **Time-speed curves for the same machine, using conventional and forced-torque drives.**

With the conventional drive the machine starts, runs through the cycle at constant speed, and then stops, all in time t. With the forced-torque drive the machine accelerates and stops more quickly, and also takes advantage of speed changing to obtain optimum speeds throughout different portions of the cycle. This is accomplished in a shorter time T. Since the distance of machine travel is the same with both drives, the total areas under the two curves are equal.

To visualise the possible increased productivity in driving a machine with this type of system, Fig. 2 shows hypothetical time-speed curves illustrating the operation of a machine with a conventional motor drive and a forced-torque drive. The conventional drive here represented runs at a constant speed, while the forced-torque drive takes advantage of the speed-changing possibilities and runs at the optimum speed for each portion of the cycle.

Areas under the various sections of the curve are the measure of the corresponding distances the machine has moved. Thus, a_1 in the lower graph is the distance (revolutions, length of stroke, angular rotation, etc.) that the machine has "displaced" during the starting period, when the speed has changed from zero to 50% balanced running speed in time t_1 with conventional drive. Similarly, the machine then continues running at 50% speed for the time t_2, at the end of which the machine is brought to a stop in time t_3 and the cycle is completed. This 50% speed represents the maximum constant speed at which this particular machine can be driven and is limited by the maximum allowable speed for the critical portion of the work cycle, e.g., when the die contacts the work in a press. However, other portions of the cycle can operate at various other speeds, up to 100%.

The upper curve, showing the same machine driven by a forced-torque drive, takes advantage of this fact and changes speed three times during the cycle, each speed being the optimum for the particular portion of the cycle. This is practical, since the forcing action and regenerative braking permit almost instantaneous starting, stopping, and speed changing. The area under the upper curve equals the sum of the incremental areas, A_1, A_2, A_3, A_4, A_5, A_6, A_7, A_8, and A_9, which is also equal to a_1 plus a_2 plus a_3 on the lower curve. In other words, the distance of machine travel, as measured in revolutions or other displacement units, is the same for both curves. The total time for the cycle, when using forced voltage acceleration, regenerative braking, and speed changing, will be T. Hence the fraction $T/(t_1 + t_2 + t_3)$ will be a measure of the ratio of total cycle time for the operation of the machine, when driven by a forced-torque drive, to the total cycle time, when driven in the conventional manner. The percentage gain is :

$$100\left[\frac{(t_1 + t_2 + t_3) - T}{t_1 + t_2 + t_3}\right]$$

The production ratio will be t/T.

From the chart it can be seen that the reduction in cycle time stems from the time required for starting and stopping, i.e., the reduction in time t_1 and time t_3, especially time t_1, and in the reduced time for portions of the cycle where higher speeds are used. The gain in production would be greatest for a cycle wherein the machine with conventional drive is started, reaches balanced running speed, and is immediately brought to a stop, so that there is no constant-speed portion or portions of the cycle. The least gain, zero per cent, is when the machine is started, comes up to speed, and is never stopped. In this application there is one optimum speed for the whole cycle. This, of course, is only a theoretical condition, but it indicates that the amount of increased production is greater as the length or duration of the operating cycle decreases, and as the number of different optimum operating speeds in one cycle increases.

It is recognised that there are factors, in addition to speeds, which limit the productivity of a machine. It may be humanly or even mechanically impossible to feed the machine as rapidly as it can be operated. The material being processed by the machine may not permit faster speeds. For example, some textile machines have their speed limited by thread breakage. All such considerations must be taken into account when analysing the drive.

To analyse the operation of a machine for the purpose of determining what may be gained with respect to greater machine productivity by adopting a forced-torque drive, the first step is to construct the actual time-speed curve for every step in the cycle of operations of the machine as driven conventionally. Starting and stopping curves should be obtained by testing the machine under running conditions. If the machine is

still on the drawing board, the speed curves must be calculated or estimated from comparable drives.

From the plotted time-speed curves, as in Fig. 2, the area under each section of each curve (displacement) and the elapsed time for each portion of the cycle are obtained. Where work is done during a period of acceleration, the approach must be modified to take account of this factor.

The time-speed curves for a machine can be determined by calculating the acceleration and deceleration time of a system from known values of inertia and the available torque from the electrical equipment. The machine cycle used must reflect all the advantages of changing to higher speeds in the process, whenever mechanically allowable. Tentative figures on the gain in machine production which may be obtained by changing to a forced-torque drive can be obtained directly from the curves.

The reason why the gain figure will be only tentative is because there are a number of other possible factors involved, and these may greatly increase the gain in production or perhaps decrease it. For this reason it is necessary to study carefully each step for the cycle of operations, to determine other possible changes and factors, such as increasing the speed of certain portions of an operation.

Every idling portion of the cycle presents possible time savings by speeding up the machine for that section of the cycle only. Examples are return strokes on planers and presses, rapid traverses on lathes, and idling time on screw machines.

In some machines running with conventional drive, attempts to change speeds mechanically result in a theoretically functioning machine, which, in practice, cannot be kept in operation because of wear and shock. Hosiery knitting machines are an example. Great gains in knitting-machine productivity have been obtained by applying electrical adjustable-speed drives, in which the speed changes with great rapidity and over a wide range, and in which required maintenance is at a minimum.

In addition to increased productivity, there are other economic gains to be obtained through the application of forced-torque drives. Machines running at constant driving speed are usually geared to run at the highest possible constant speed. This speed tends to be too great for those portions of the cycle which should operate at the slowest speed. For example, in the draw-press operation, at the moment the die makes contact with the sheet the speed should be slow. A high speed would tend to shift the sheet, causing work spoilage. To run the machine more slowly would reduce production correspondingly. Therefore, the practice is to accept a certain amount of such spoilage as being necessary. With a forced-torque drive, however, it is simple to reduce the speed for the short duration in which the die is making contact with the sheet. Work spoilage is correspondingly reduced.

Another factor in favour of the forced-torque drive is reduced maintenance. The rapid accelerations and controlled speed changes are cushioned throughout. The driven machine requires no brake or clutch. Hence, there is no cost for maintenance of these items; and of perhaps more importance, there is no down-time required for adjusting clutches or brakes.

SWITZERLAND

Production of Spheroidal Graphite Cast Iron by Treatment with Argon

By P. KÖNIG and B. MARINCEK. (From *Schweizer Archiv*, Vol. 20, No. 2, February, 1954, pp. 41-44, 2 illustrations.)

IN another report[1] on characteristic precipitation forms of graphite as a result of zinc treatment of superheated cast-iron melts with a high sulphur content, the authors discuss the possibilities of producing granular or spherical graphite without spheroid distortion in polarised light. They relate the uniform precipitation of this granular graphite to the following conditions :— (i) The manganese content should remain below 0·1%; (ii) the carbon content should not exceed 2·6%; and (iii) the degree of saturation of carbon, calculated from the simplified formula

$$S_C = \%\ C/(4{\cdot}3 - \tfrac{1}{3}\%\ Si),$$

should not be greater than 0·75. If these requirements are fulfilled, then, owing to the influence of the zinc, there will be no sulphide precipitations, in spite of a high sulphur content (see V-83 in Table I). The actual function of the zinc, which boils at 906° C, is not described in the above work, and will be examined in the present paper, in which the problem of non-laminar graphite precipitation of zinc-treated iron with low sulphur contents has been studied on a Swedish pig iron. This was melted with practically carbon-free ingot iron (Table I), according to requirements. These iron-carbon alloys were melted in a basic induction furnace in quantities of 500 grams and for deoxidation were initially provided with 0·5% ferro-silicon (98% Si).

The zinc-treated melts, with carbon contents below 2·5%, were injected with 0·75 and 2·5% ferro-silicon before pouring and showed some imperfectly developed spheroids of graphite in pearlitic fields, which were free from flake graphite. These fields were bounded by a network of flake graphite. The zinc was introduced carefully in the form of small granules on the surface of the bath.

In connection with the spheroidal graphite precipitation, it was suspected that the effectiveness of the zinc, which boils well below the solidification temperature of cast iron, might be due in the first place to the rinsing action of this metal in vapour form. The zinc probably has only a purely physical importance, since chemically it is the most inactive metallic component of the irons investigated.

TABLE I. COMPOSITION AND TREATMENT OF MATERIALS TESTED.

Type of material	%C	%Si	%Mn	%S	%P	S_C	Argon treatment temp., °C	Period of treatment, min
Swedish pig iron	4·13	0·09	0·10	0·013	0·048			
Ingot iron	0·02	0·002	0·13	0·026	0·015			
V-83	2·56	2·07	0·03	0·440		0·71		
V-113 (Fig. 1)	1·25	2·96	0·12	0·016		0·38	1350	15
V-116 (Fig. 2)	2·33	2·77	0·12	0·016		0·69	1500	10
V-119	2·48	3·29	0·19	0·016		0·77	1500	10

ARGON TREATMENT

Genner[2] investigated the theoretical and practical problems of degasification by introduction of inert gases in metal baths and pointed out that, for a constant quantity of gas, the degassing action of the inert gas increases with decreasing bubble diameters. The solubility of the gas dissolved in the metal bath is either simply proportional to the partial pressure of the gas in the

gaseous phase or proportional to the square root of the partial pressure, the latter case being the most frequent in practice. A distinction is made between two types of gas solubility, *viz.*:—(1) Simple solution (endothermic process), and (2) compound solution (exothermic process).

A simple solution represents an accumulation of gas atoms, whereas a compound solution is the result of an absorption of gas ions in the metal lattice. The solubility of the gases increases with temperature in the case of a simple solution, with a sudden increase in gas absorption at the melting point. Usually, there are also discontinuities at the transformation points of the solid-metal phases on the constant-pressure lines for metal-gas systems[3]. Seeliger[4] found no rare gases dissolved in measurable quantities in solid metals; on the other hand, a very slight solubility of these gases has been observed in the liquid metals.

Tests with argon:—In order to increase the suspected action of a zinc treatment of cast-iron melts, the introduction of zinc was preceded by a 15-minute treatment with argon at 1350° C. The argon available was of 99·8% purity, with about 0·01% oxygen and 0·01% hydrogen. Introduction of the gas was achieved by means of a quartz tube dipped into the metal. After the zinc treatment, the metal was injected with 2·5% ferro-silicon. The material thus treated now suddenly showed only graphite in spheroidal form; the contours were not yet absolutely circular but there was complete absence of flake graphite. It was considered that the hypothesis of a degassing action of zinc in vapour form could be regarded as confirmed, if it were possible to produce exclusively spheroidal graphite by treating a cast-iron melt with argon only. Subsequent tests fulfilled expectations beyond any doubt, and precipitation of spheroidal graphite was obtained in an improved form.

If, therefore, in the previously mentioned tests of cast irons with a high sulphur and a low manganese content, the precipitation of the iron sulphides did not occur as a result of the action of the zinc, and if it is assumed that the microscopically discernible iron sulphides have an oxygen content, then it appears as if the zinc in vapour form has the ability to displace the dissolved oxygen, as long as the manganese content is below 0·1%.

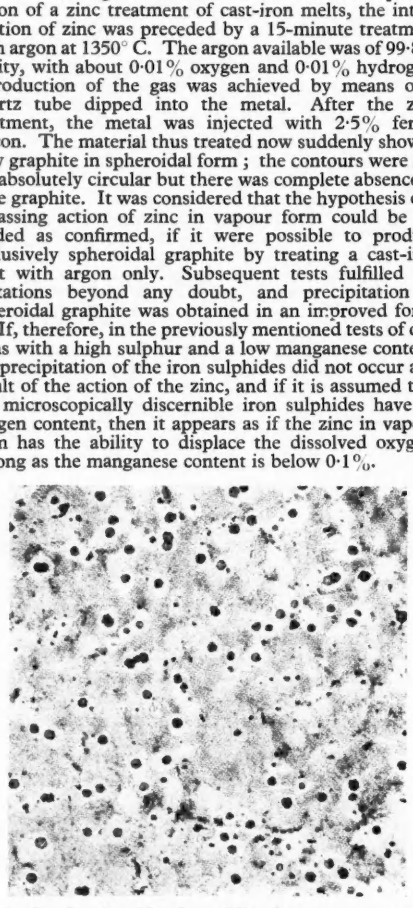

Fig. 1. **Small spheroids of graphite after argon treatment of melt V-113; etched with nital (×100).**

The material in test V-113 which, with the exception of the zinc addition, was treated according to the above described procedure, is illustrated in Fig. 1, which shows numerous spheroids of graphite, uniformly spherical in shape. In Table I, the degree of saturation (S_C) for carbon is surprising, as it corresponds to that of a strongly hyper-eutectoid steel.

In similar tests with an iron containing 3·0% carbon, the graphite spheroids first appeared again only after the temperature was raised to 1500° C during the argon treatment. The time of treatment was 10 minutes. According to these results, it appears that, if it is desired to obtain spheroidal graphite precipitation, a proportionality relationship must be observed between the carbon content and the temperature at which argon treatment is carried out. Fig. 2 (test V-116) shows a hypo-eutectoid cast iron with graphite spheroids, the contours of which are deceptively similar to those of cast iron treated in zinc.

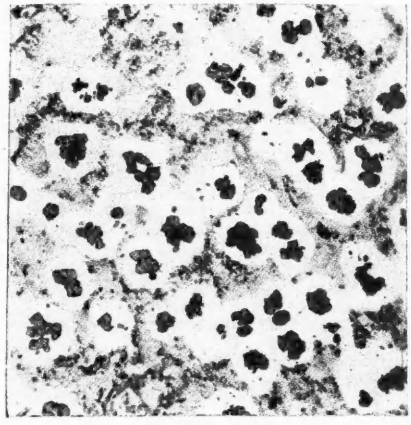

Fig. 2. **Coarse graphite spheroids in hypo-eutectoid cast iron V-116 treated with argon; etched with nital (×100).**

Up to this stage, the irons investigated had a low manganese content of about 0·1%. Subsequent tests were carried out to observe the influence of increased manganese content on spheroidal graphite precipitation. The quantities of manganese added amounted to 0·1, 0·2, and 0·5%. All three irons were sand-cast and showed no, or only very few, spheroidal graphite formations. The material in test V-119 with 0·19% manganese was also chill-cast in graphite, to study the effect of increased rates of cooling. With increasing cooling rates, the following changes in the graphitising tendency were observed:—

(1) *Cooling in the sand mould:*—Fine flake graphite, surrounded by areas of ferrite, interspersed with pearlite.

(2) *Chill-cast in graphite:*—
   (a) Centre of specimens:—Network of fine eutectic graphite, with isolated graphite spheroids; ferrite beside pearlite.
   (b) Intermediate zone:—Coarse, dense eutectic graphite, with an increasing number of small spheroids; cementite beside ferrite and pearlite.
   (c) Boundary zone:—Spheroids only; no ferrite; pearlite and increased formation of cementite.

These tests indicate the importance of the rate of cooling on the graphite formation of an iron with a weak tendency to spheroidal solidification.

(*Concluded on page* 197)

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Radioisotopic, High-Potential, Low-Current Batteries

By J. H. COLEMAN. (From *Nucleonics*, Vol. 11, No. 12, December 1953, pp. 42-45, 9 illustrations.)

As a result of the interest shown by readers in our recent Blue Page item on nuclear storage batteries, we are publishing the following article, which provides additional information on this subject.

GENERATION of electric energy by collecting the beta particles emitted from a radioactive source with an electrode insulated from the source by a solid dielectric has been found feasible with polystyrene as the insulator.

The principle of operation of direct-conversion devices in general can be illustrated by generators utilising a vacuum dielectric[1-5]. As early as 1913, Moseley[1] obtained a high electric potential by collecting the beta particles emitted from a radioactive source suspended in a vacuum. Moseley's apparatus consisted of two concentric spheres with a vacuum connection to the outer sphere for evacuation. The centre sphere or source electrode was a quartz bulb containing approximately 20 millicuries of radium. The wall of the bulb was sufficiently thin to enable penetration of the emitted beta particles, but thick enough to absorb the alpha particles.

This source of beta electrons was supported by a thin insulating quartz rod attached to the inside wall of the outer sphere, which collected the electrons. The inner and outer spheres were covered with a conducting coating of silver, forming the anode and cathode, respectively. Any potential difference between the electrodes was measured by an attractive disc-type electrometer located in the mouth of the vacuum connection.

On evacuation of the inter-electrode space, Moseley repeatedly measured about 150 kV on the source electrode before internal flash-over discharged the device. A simple capacity-charging relationship was noted after each discharge for a beta charging current of about 10^{-11} A.

In 1952, Linder[2] published results on two vacuum devices similar to Moseley's, using a Sr^{90}-Y^{90} fission-product source. In one device, with improved vacuum techniques and electrode design, a potential difference of 365 kV was obtained. In the other device, a direct electrical connection to the source electrode was made through an external insulator, which formed part of the vacuum enclosure. A somewhat lower voltage was obtained with this device, owing to surface leakage on the external part of the insulator exposed to the atmosphere. A capacity-charging curve across a resistive load was measured by Linder for an equivalent circuit of a beta-current source, a capacity, and an internal resistance in parallel with the external load. The internal resistance was a combination of surface conduction across the insulator bushing and some conduction through the vacuum by cold emission or residual gas.

In 1951, a project was started to develop a solid insulator which could be substituted for the vacuum dielectric in the direct-conversion generator, so as to increase reliability.

The literature at that time stated, however, that insulators were both lowered in electrical resistivity[6] and physically degraded[7] by ionising radiation. These effects are not limitations in the vacuum generators, since insulator bushings can be shielded from the radiation. On the other hand, when a solid is substituted for a vacuum, the radiation must penetrate the solid dielectric itself for operation of the device. Thus, to determine the feasibility of a solid-dielectric type of radioactive battery, a test programme was started on commercially available insulators.

EXPERIMENTAL DATA.

For geometrical simplicity, tests were made using flat sheets of insulation between the faces of cylindrical source and collector electrodes, as shown in Fig. 1. As a beta source, 25 mc of Sr^{90}-Y^{90} were deposited in an electrode formed by an aluminium cup covered with aluminium foil. An aluminium disc, opposite this source electrode, collected the beta particles after penetration of the insulator. Lead shielding was used around the aluminium collector and aluminium source electrode to reduce the bremsstrahlung below tolerance at the surface.

In operation, the beta current collected through a polystyrene insulator, 0·002 in. in thickness, was measured with an electrometer and was found to be about 50×10^{-12} A at zero voltage. The total beta current emitted from 25-mc Sr^{90}-Y^{90} is 300×10^{-12} A; however, one half of the current is emitted in an opposite direction from the collector and is absorbed in the aluminium cup. The remaining loss of current is due to absorption in the thin aluminium sheet covering the cup and in the insulator itself.

Charging voltage:—The open-circuit charging voltage was measured as a function of time by an electrometer voltmeter with negligible capacity. The resulting voltage, V (the lower curve in Fig. 2) for the 0·002-in.-thick polystyrene insulator showed an exponential rise with time, t, to a maximum of 200 V.

As in the case of the vacuum generators of Moseley and Linder, capacity charging of this type is given by the equation

$$V = RI_B(1 - e^{-t/RC}) \quad .. \quad .. \quad (1)$$

where R is the total internal and external resistance in parallel, C is the total capacity, and I_B is the beta current. The maximum charging voltage, V_{max}, for $t \gg RC$, is

$$V_{max} = RI_B \quad .. \quad .. \quad (2)$$

Next, the initial rate of charge is found by expansion of eq. (1) for $t \ll RC$ to be independent of R and given by

$$V_0 = I_B t/C \quad .. \quad .. \quad (3)$$

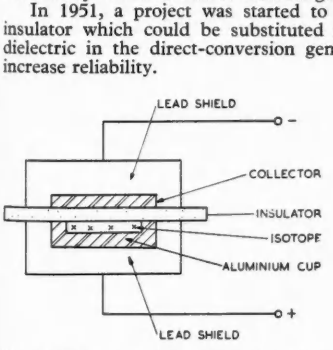

Fig. 1. **First experimental model of generator with solid insulator.**

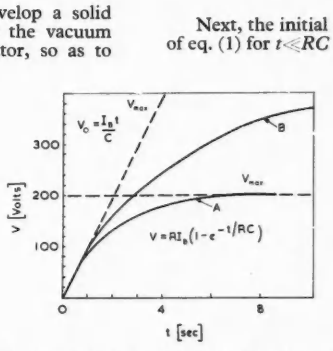

Fig. 2. **Charging voltage *vs.* time for 0·002-in. polystyrene after irradiation for a few minutes (A), and for several hours (B).**

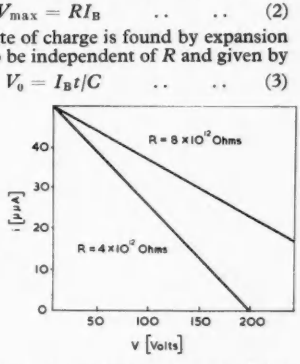

Fig. 3. **Current-voltage characteristics of 0·002-in. polystyrene sheet under conditions of Fig. 2.**

Thus, from eq. (2), for V_{max} of 200 volts and I_B of 50×10^{-12} ampere, R is 4×10^{12} ohms.

Irradiation effect on insulator :—After several hours, a second measurement of the charging voltage as a function of time was made, and V_{max} was found to have increased to 400 volts, as shown by the upper curve of Fig. 2, indicating an increase in insulation resistance to 8×10^{12} ohms, while the initial charging rate remained the same. Consequently, a direct measurement of internal resistance, R_I, was made by applying an external voltage to the generator terminals and recording the resulting current with the electrometer.

The current-voltage characteristics for an unused 0·002-in.-thick polystyrene sheet is shown by the lower curve in Fig. 3. The straight line indicated an ohmic resistance of $R_I = 4 \times 10^{12}$ ohms, which can be calculated by inverse of the slope or

$$R_I = \frac{V}{I - I_B} \quad .. \quad .. \quad (4)$$

On continued irradiation, the current-voltage characteristic (upper curve in Fig. 3) showed a decrease in slope or increase in resistance to $R_I = 8 \times 10^{12}$ ohms, both values of R agreeing with the results in Fig. 2.

Next, to measure this apparent change in resistance after irradiation, a fresh sheet was inserted between the electrodes (Fig. 1) and a constant voltage applied while the source was covered with an absorber. The absorber was removed after the normal polarisation current decreased to a low value (the corresponding volume resistivity $\rho = 10^{18}$ ohm-cm) and the induced current recorded. The calculated resistivity was found first to drop to about 10^{16} ohm-cm, to decrease further for a few minutes to a minimum of about 10^{15} ohm-cm, and then actually increase in resistance after one day, with approximately the square root of the time. Details of this effect were given in a previous paper[8].

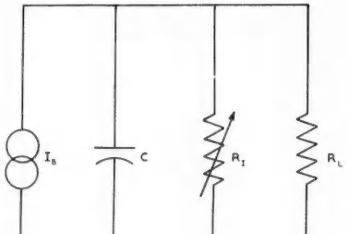

Fig. 4. **Equivalent circuit of battery using solid dielectric which increases in resistance with time of irradiation.**

Thus, the equivalent circuit in Fig. 4 of a generator using a solid insulator can be deduced from eq. (1) and from the observed induced conductivity effect in solid insulation. This circuit is similar to that of the vacuum generator, except that the internal resistance R_I is a variable, being a function of the total time of irradiation and of the incident beta-current density. All good insulation (i.e., unirradiated $\rho > 10^{16}$ ohm-cm) showed this effect; however, an accelerated life test, using a 250-mc source, eliminated all plastic insulators but polystyrene, owing to physical degradation. For example, the fluorocarbons Teflon and Kel-F increased in resistance for a few weeks, then became brittle, and shorted the electric circuit; polyethylene increased in resistance for a week, then began to decrease, owing to slow degradation. Polystyrene, on the other hand, has increased in resistance for over one year.

On the basis of these results, the test source of Fig. 1 was potted in plastic and demonstrated in January, 1952, as a radioactive battery. Since that time, models B-50 and D-50 have been built, reducing the size and weight, and increasing the safety for the same current output of 50 $\mu\mu$A.

BATTERY DESIGN AND CHARACTERISTICS.

Model B-50 is shown in Fig. 5. A beta source of 10 mc of Sr^{90}-Y^{90} is welded between two strips of 0·0005-in.-thick gold foil, 2 in. long and $\frac{1}{4}$ in. wide. The active area extends $\frac{1}{4}$ in. from the bottom end and is surrounded by a "U"-shaped aluminium collector, $\frac{1}{8}$ in. thick, which is supported by a lead shield.

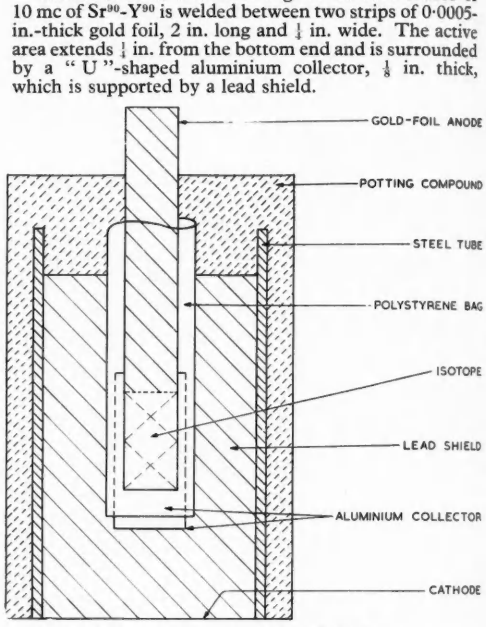

Fig. 5. **Schematic layout of Model B-50 generator.**

A slot for insertion of the source and insulator was formed by pouring the lead around a stainless-steel jig, which held the aluminium collector in position in a steel tube. The jig was removed after the lead cooled, and the source was placed in two polystyrene bags and inserted in the slot. One bag, $\frac{3}{8}$ in. wide and $1\frac{1}{4}$ in. long, was inside a larger bag, $\frac{1}{2}$ in. wide and $1\frac{3}{8}$ in. long. Both bags were made by folding 0·005-in. Plax polystyrene along the long dimension and heat-sealing along a $\frac{1}{4}$-in., "L"-shaped border, leaving the top open. "Biwax" potting compound was poured around the outside of the unit, and the output characteristics were measured.

First, the average output current for twenty-five batteries at zero voltage was found to be $I_B = 40 \times 10^{-12}$ A out of a total available current of 120×10^{-12} A, a 33% current-collection efficiency. Most of the 67% loss was due to absorption in the gold foil of most of the Sr^{90} beta particles and some of the weaker Y^{90} beta particles.

The initial rate of charge of the output voltage, measured across an electrometer voltmeter, was found to be 1·2 volts/sec and the capacity was calculated for eq. (3) to be $C = 30\ \mu\mu$F. This capacity is slightly higher than the capacity of 25 $\mu\mu$F measured on a bridge, since a high-resistance contact to the surface of the insulator by ionisation of the air between the source and collector reduces the effective spacing between the source and collector electrode. Also, polarisation current and trapped beta particles were found to be a significant part of the current when the voltage was changed. For example, it was necessary to wait several minutes on shorting the terminals before the current reduced to its original value at zero voltage.

The maximum charging voltage across an electrostatic voltmeter after two months was increased from a few hundred to 6000 V, which, from eq. (2), corresponds to an internal insulator resistance of $1{\cdot}5 \times 10^{14}$ ohms. Model B-50 had a higher current-collection efficiency than the original unit shown in Fig. 1, since the collector electrode surrounds the source. The dense gold source electrode, however, increased the bremsstrahlung and, consequently, the shielding.

Model D-50 :—In the third model, D-50 (Fig. 6), the radioisotope is deposited directly in the polystyrene insulator, which is machined in the form of a cup, $\frac{1}{16}$ in. in diameter and $\frac{3}{8}$ in. in length, with a $\frac{1}{32}$-in. wall. Contact is made to the isotope source by a 0·005-in.-diameter monel-wire loop, which is soldered to a $\frac{1}{8}$-in.-diameter copper rod held in a $\frac{1}{4}$-in.-diameter polystyrene plug. A solvent such as toluene is used to seal the open end of the capsule to a groove in the plug after the isotope is inserted. The plug and capsule fit into a cylindrical aluminium collector, $\frac{3}{8}$ in. in diameter and $\frac{3}{4}$ in. in length, held in the lead shielding and copper tube. The wax potting compound used in the B-50 was replaced by polystyrene, to reduce surface leakage. When the complete battery was assembled, swab tests were made to detect any radioisotope leakage. The measured radiation of model D-50 was approximately the same as that of model B-50 ; however, the volume, including shielding, was reduced from 4 cu in. to 1 cu in. by the elimination of the gold source electrode. In model D-50, the only dense material within range of the beta particles is the monel wire, which has a small cross-section.

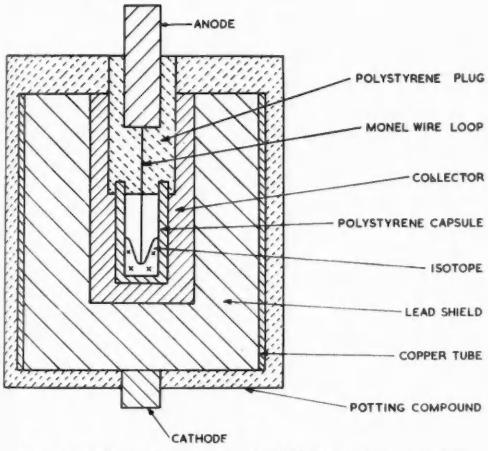

Fig. 6. **Schematic layout of Model D-50 generator.**

Next, the electrical characteristics were taken, as in the case of the B-50. The current at zero voltage was again 40 $\mu\mu$A ; the battery capacity was approximately 5 $\mu\mu$F for a charging rate of 5 volts/sec across an electrometer, which added 3 $\mu\mu$F ; the maximum voltage was 7000 V after two weeks shelf life. This beta current represents a 33% collection efficiency of the 120×10^{-12} A emitted from the isotope. Most of the lost current in this case is absorbed in the $\frac{1}{32}$-in.-thick insulator wall. This thickness, however, increases the breakdown voltage to approximately 30,000 V. For special applications, where the maximum voltage required is only a few hundred volts, the insulator thickness can be correspondingly reduced, to obtain an increase in current (at a sacrifice of mechanical strength). Also, for lower current applications, the shielding can be decreased for the same external radiation.

The output voltage decreased when a battery was exposed to room atmosphere in a fully charged condition for more than a few hours, owing to electrostatic precipitation of dust and, consequently, surface conduction across the external insulation. Contamination of the polystyrene surface was less serious than in the case of the wax potting compound. In either case, however, the dust could be removed with soap and water, followed by a thorough drying.

Development work is continuing on improving the mechanical seals, to decrease the possibility of any isotope leakage. It appears, however, that the present geometry gives about the minimum volume with a 10-mc source for an external radiation which is below tolerance at the surface. For lower currents, the shielding can be scaled down accordingly.

Applications.

Batteries using radioisotopes as an energy source offer, in principle, the advantages of long life under extreme operating conditions, as the nuclear process itself is essentially unaffected by temperature or pressure. The half-life of the Sr^{90}-Y^{90} isotope is approximately 25 years ; however, a wide choice of half-lives is available. The extrapolated life of the polystyrene insulation from the 250-mc tests has exceeded 25 years for the 10-mc batteries, or 250 years for a 1-mc battery. As no chemical reactions or solid-state effects are used in the power generation, the insulation appears to be the only critical feature.

Thus, for applications requiring small currents, such as ionisation chambers, these batteries should offer the advantages of smaller size, less weight, and lower cost, since most of the power available from conventional chemical batteries is not used. In this connection, it is estimated that an ionisation-chamber power supply producing up to 10,000 V with a charging current of 10 $\mu\mu$A could be manufactured in quantity for under five dollars at the current price of Sr^{90} of fifty cents per mc. Also, in applications requiring operation over a period of many years at low temperatures, these batteries appear to be more reliable than batteries depending completely or in part on a chemical reaction.

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PRODUCTION OF SPHEROIDAL GRAPHITE CAST IRON BY TREATMENT WITH ARGON

(*Concluded from page* 194)

Summarising, it may be said that, in analogy with the tests with zinc on cast iron with a high sulphur content, the above tests show that a uniform spheroidal or granular graphite precipitation in hypo-eutectoid irons is related to a manganese content which must be below a value of 0·1—0·2%. It is highly probable that satisfactory degassing by zinc or by treatment with argon can be obtained only below this critical figure for manganese concentration. It should also be pointed out that a higher manganese content can also raise the solubility of oxygen in the iron, because manganese, with its high affinity for oxygen, forms a relatively stable compound, with a melting temperature of 1650° C. With an exothermic oxygen solution of this kind, oxygen solubility would also be greatly increased, particularly in the solid material.

Properties and Applications of Rhenium

By L. W. KATES. (From *Materials and Methods*, Vol. 39, No. 3, March 1954, pp. 88-91, 5 illustrations.)

Rhenium, which resembles manganese in its chemical properties and tungsten in its physical properties, has been neglected until recently, owing to fabrication difficulties. Now, however, rhenium in ductile form is being investigated for a variety of applications, such as thermocouple alloys and electrical contacts. Other applications are certain to develop after its characteristics become better known.

RHENIUM has been found in widely scattered locations all over the world, but it is still a relatively rare metal, being about one-thousand times less abundant than molybdenum. Rhenium does not occur as a massive mineral, but is often found as a minor constituent in molybdenite, a molybdenum sulphide ore. Most of the rhenium at present obtainable in the U.S.A. is derived from flue dust from molybdenite-bearing copper ores.

PHYSICAL AND MECHANICAL PROPERTIES

Among the metallic elements, the melting point of rhenium (5738° F) is exceeded only by that of tungsten (6616° F). Rhenium has a higher density (0·75 lb/cu in.) than those of the more common refractory metals. Only platinum, iridium, and osmium have higher densities. The electrical resistivity is about four times that of tungsten at room temperature and remains somewhat higher at elevated temperatures.

The boiling points of rhenium and tungsten are about the same (10,650 and 10,700° F respectively). It has been stated that the vapour pressure of rhenium at temperatures around 4500° F is somewhat lower than that of tungsten. This factor is of particular significance in lamp and electronic applications. It is possible, however, that these observations are not indicative of a lower vapour pressure for rhenium but, rather, that rhenium does not deteriorate as rapidly as tungsten in a slightly moist atmosphere at elevated temperature, owing to repeated oxidation and reduction. Present indications are that rhenium is very much less likely to be attacked by this " water-cycle " treatment.

The crystal structure of rhenium is hexagonal close-packed, while those of tantalum, molybdenum, and tungsten are all body-centred cubic. This suggests that rhenium would not be quite as readily deformed as the other materials. The coefficient of linear expansion is given as $6{\cdot}9 \times 10^{-6}$ per °F along the hexagonal axis, while the coefficient perpendicular to this axis is much lower, $2{\cdot}6 \times 10^{-6}$ per °F. The average expansion in a randomly oriented, fine-grained piece would then be somewhere between these two figures and could be expected to be somewhat higher than those for tungsten and molybdenum, which are $2{\cdot}4 \times 10^{-6}$ per °F and $2{\cdot}7 \times 10^{-6}$ per °F, respectively.

Because of fabrication difficulties, it is a problem to obtain pieces large enough for testing, and little information is available on the mechanical properties. The tensile strength of vapour-deposited material is about 70,000 psi, with a ductility, as measured by the elongation, of 24%. Some data have been obtained for metal prepared by powder-metallurgy techniques and these indicate that the tensile strength of annealed material is in excess of 120,000 psi, while the ductility is about 25%. Some preliminary data on the modulus of elasticity indicate that it is high, in excess of that for tungsten, which is 50×10^6 psi.

Rhenium is somewhat more resistant to abrasion than tungsten. The hardness of annealed rhenium is 247 Vickers, while that of annealed tungsten is 392.

CORROSION RESISTANCE

Massive rhenium is not attacked by atmospheric air at room temperature; rhenium powder, however, as well as porous compacts left exposed to air, forms an oxide which hydrolyses to perrhenic acid, so that the oxide formed is not a protective one. Rhenium oxidises in about the same manner as tungsten, when heated to 1830° F in air. It begins to oxidise in air, however, at a temperature as low as 750° F.

Rhenium can be heated to any temperature in an atmosphere of wet or dry hydrogen without any attack. Hydrogen is a suitable atmosphere for high-temperature sintering of powdered compacts. Rhenium is unaffected by dry, pure, inert-gas atmospheres. The halogen gases, however, attack it. The metal is resistant for long periods to attack by hydrochloric acid, but is attacked by nitric acid and hot sulphuric acid.

FABRICATION

Rhenium has not been fabricated into massive metal forms, such as wire, rod, and strip, until very recently, because several of its properties make it difficult to work. Although small buttons have been arc-melted, rhenium has the same limitations for melting as have tungsten and tantalum. Molybdenum, on the other hand, with a melting point several hundred degrees lower, is now melted and cast commercially.

The use of powder-metallurgy methods would appear to be a straightforward way of preparing the material. Up to a certain point, this is true. Rhenium can be sintered to densities in excess of 90% of theoretical, and after sintering it does not have the brittleness found in tungsten.

In the mechanical-working steps, however, the greatest difficulties occur. Ingot after ingot of the material has been sintered to high density, has exhibited excellent room-temperature and elevated-temperature ductility in the early deformation steps, but has failed in the later stages of working. This is due to an extremely rapid rate of deformation hardening, probably higher than that for any other known metal. This means that relatively light reductions in cross-section must be made between anneals; otherwise, the material will become overworked and will crack. To complicate matters further, if only light passes are taken, the annealing temperature, to obtain complete softening, is in the vicinity of 2700° to 3600° F. As an example, the hardness of annealed rhenium is about doubled as a result of a 10% reduction in area. A comparable reduction in area for tungsten causes an increase of about 8% in hardness. This problem can be minimised by careful working at the proper temperature. It is actually a desirable property for wire drawing, because the wire, after passing through the die, has been so strengthened, even though the cross-section is decreased, that there is no tendency for the wire to break under the pull necessary to draw it through the die.

An indication that rhenium has low notch sensitivity was obtained during wire drawing. Transverse cracks formed when a piece of wire was overworked as it was pulled through the die but, despite a reduction in cross-section of about 20 to 25%, resulting from the cracks, no failure occurred.

In spite of the problem introduced by rapid deformation hardening, rhenium can be readily formed. It is very ductile in the annealed state and, provided it is shaped with a minimum of cold work in any particular area, no difficulty is introduced. It can be bent, coiled, rolled, swaged, and drawn at room temperature, if proper precautions are observed.

APPLICATIONS

Many possible uses for rhenium have been suggested, but most of these have not been investigated because of the unavailability of massive metal. Applications which do not require metal in this form, such as catalysts, electrical-contact alloys, thermocouple alloys, and wear-resistant alloys, have received the most attention.

Colloidal rhenium has been prepared for use as a catalyst and shows some promise in certain organic reactions. Alloys containing less than 10% rhenium have been investigated for electrical make-and-break contacts and have shown very good resistance to transference of the metal during operation. Thermocouple alloys of the platinum-rhodium type, with rhenium substituted for all or part of the rhodium, are interesting because of the high e.m.f. they generate compared with the conventional platinum vs. platinum-rhodium couple. At 2200° F, for example, a Pt/Pt-8% rhodium alloy gives an e.m.f. of about 12 millivolts, while a Pt/Pt-8% rhenium alloy gives about 30 millivolts. Alloys prepared by powder-metallurgy methods, composed of 50 to 99% rhenium with tungsten, nickel, molybdenum, and other metals, have been used successfully for pen points and have shown excellent wear resistance.

Rhenium appears to have considerable potentialities as a material for electronic applications. Its high melting point, ductility after high-temperature treatment, and high electrical resistivity make it a particularly promising material for such applications as cathode and filamentary emitters and heater wire for indirectly heated cathodes in electronic tubes. Its high electrical resistivity at elevated temperatures, compared with that of tungsten, permits an increase in the permissible wire diameters used, thus leading to more rugged filaments or heaters.

Rhenium appears promising for incandescent-lamp filaments. It is affected only slightly by the "water cycle," so that bulbs with rhenium filaments would not tend to blacken nearly as much as tungsten-filament lamps. Also, tungsten may become brittle after prolonged heating at very high temperatures, while rhenium remains quite ductile. The higher resistivity of rhenium may also be useful in this application, permitting somewhat heavier filaments to be used for a given power input.

There are probably other uses for rhenium which have not yet been considered. The fact that it apparently does not form carbides, for example, suggests the possibility that rhenium probes, or even constructional parts, can be placed in contact with carbon or graphite at very high temperatures without embrittlement. In this connection, the high melting point of the metal is an indication that the high-temperature creep and rupture strength are probably good, so that it may be usable as a structural material at elevated temperatures in non-oxidising atmospheres. Finally, the field of ductile high-rhenium alloys has not been extensively investigated.

GERMANY

Improvements in the Manufacture of Transformer Sheet

By H. H. MEYER and H. SCHLÜTER. (From *Stahl und Eisen*, Vol. 73, No. 26, December 17, 1953, pp. 1706-1717, 13 illustrations.)

This article reviews the improvements achieved during the past fifteen years in the manufacture of transformer sheet with minimum iron losses and compares results obtained in Germany with those of other countries.

PART I

Most silicon steels, with from 0·5 to 4·5% Si, are still produced by hot rolling as sheets of 0·35 or 0·50 mm in thickness. A report on gradual improvements in hot-rolled sheets as regards iron losses was published by Houdremont[1]. Starting with unalloyed cast steels, the L_{10}* values for iron losses decreased from 6 W/kg in 1885 to 5 W/kg in 1900. The use of silicon steels reduced the losses to 2 W/kg in 1904, to 1·3 W/kg in 1913, and to 0·78 W/kg in 1940. From then until 1950, the value was reduced to about 0·55 W/kg, and the question now arises as to whether further important improvements can be expected in the commercial manufacture of transformer sheet.

The iron losses consist mainly of hysteresis and eddy-current losses. The width of the hysteresis loop and its area depend on the coercive force. For a lamination 0·35 mm thick, with an iron loss of 0·8 W/kg at 50 cycles, the coercive force is about 0·25 oersted. Coercive forces as low as 0·10 to 0·15 oersted were obtained with experimental alloys containing 3·5 to 4·5% Si under manufacturing conditions. For a sheet of 0·35 mm, this would correspond to an L_{10} iron-loss value of about 0·6 W/kg. However, such low values are very difficult to attain with sheets of less than 1 mm thickness, and the production costs are so high that further noteworthy improvements with respect to the iron losses of high-silicon transformer sheet seem improbable, insofar as the manufacture of large quantities is concerned. Eddy-current losses could be reduced by decreasing the sheet thickness and by raising the silicon content, so as to increase the specific electrical resistance. However, a reduction in thickness cannot be considered for economical reasons and because of the stacking factor.

CHEMICAL COMPOSITION OF SHEET STEELS

A further increase in the silicon content[2] raises practical difficulties, owing to the fact that higher silicon contents result in sheets which are too brittle for working. The authors' experience with a melt containing 4·8% Si was that lower iron losses could be attained under much less favourable working conditions. An ingot of this melt was stripped while still hot and was placed immediately in a reheating furnace, where it was heated to the normal rolling temperature and then bloomed. The other ingots of the same melt were allowed to cool in the chill, and then reheated before rolling into sheets and final rolling to sheets of 0·35 mm in thickness. The iron losses for the non-cooled ingot were 0·81 W/kg (L_{10} value) and 1·96 W/kg (L_{15} value), whereas the ingots cooled after casting reached corresponding values of 0·88 and 1·96 W/kg.

The non-cooled ingot not only had a lower L_{10} iron loss but was also more suitable for production. Bending tests on this ingot gave a bend-test number of about unity, so that the cutting (and stamping) abilities were also reduced. Thus, a higher silicon content gives a slight improvement in iron-loss values, but does not, however, justify the difficulties in working.

Replacement of part or all of the silicon by aluminium has been suggested by Bozorth, Williams, and R. J. Morris, Jr.[3], but this has been used only occasionally for special requirements, probably because of melting difficulties. It is reported from England that aluminium contents of 0·5 to 1·0% have been found very satisfactory; in Germany, quantities of up to 0·5% Al are frequently used.

Arsenic-iron sheets obtained by Dahl, Pawlek, and Pfaffenberger[4] gave useful results, with low iron losses. The arsenic was alloyed by a diffusion process. This method may have possibilities for thin, electrolytically deposited or sintered-powder-type sheets.

In the years after the second world war, it was hardly possible to obtain previous peak values on a large scale. It was therefore necessary to have a clear idea of the causes. It has been known for many years that low iron losses are obtained only with steels having as few impurities as possible, particularly as regards carbon,

*L_{10} = Iron loss at 10,000 gauss.

manganese, sulphur, phosphorus, copper, and chromium. Maximum permissible values are 0·15% Mn, 0·01% S, 0·01% P, 0·10% Cu, and 0·04% Cr.

With regard to the carbon content, an upper limit of 0·05% is frequently specified. This is certainly valid for the finished sheet and for best results it should not exceed 0·01 to 0·02%. This requirement should not, however, apply to the melts. If the carbon content is too low, then, during the melting process or the subsequent hot working, an excess of oxygen may be absorbed, with unfavourable effects on the magnetic properties. The most suitable carbon content depends on the conditions during hot working and the annealing process. From the authors' experience, very good grades of sheets can still be obtained with 0·07% C in high-silicon transformer sheet, provided that suitable manufacturing methods are employed. A report on the metallography of silicon-iron alloys with 4% Si was published by Harry[5]. Observations were made on cementite, silicon carbide, and a eutectoid-like phase with 0·012% C.

Statistical investigations by Hengstenberg[6] at the Krupp works during the years 1938 to 1943 gave the following results :—If melts with an L_{10} iron loss of less than 0·9 W/kg are regarded as "good," then the percentage of "bad" melts decreases with increasing silicon content, ranging from 52% bad with 4·2% Si, to 30% with 4·68% Si.

Fig. 1 (a) shows the influence on iron losses of the chromium and aluminium contents of the silicon iron used. Aluminium contents are indicated on the abscissa, and chromium contents on the ordinate. The dividing line shows only 23% "bad" melts in the field on the lower left-hand side, whereas there are 75% "bad" melts on the right-hand side beyond the dividing line.

Additional information is given in Fig. 1 (b), which shows that, by increasing either the aluminium or the chromium content in the silicon iron, the number of bad melts with an iron loss greater than 0·9 W/kg increases. Moreover, it was found that the melts which were still good, despite a high chromium and aluminium content, also had a greater percentage of silicon than the bad melts with low aluminium and chromium contents. On the basis of the silicon and chromium contents of the steel and the aluminium contents of the silicon iron used, it is therefore possible to predict fairly accurately the suitability of a melt for iron losses below 0·9 W/kg.

In another series of tests, in which five melts with 3·7 to 4·1% Si were worked under similar conditions, the two melts, which were produced with a silicon iron particularly rich in aluminium (the aluminium was probably in the form of alumina), gave considerably higher iron losses (1·2 W/kg) than the melts with 0·45% Al melted in the silicon iron. Not only the iron losses, but also the permeability values, show a very marked deterioration as a result of the undesirable constituents (average decrease of 50% in μ_{20} and μ_{100} values).

Further investigations of transformer steels with lower chromium contents (0·01%) indicated that all the melts with less than 0·40% Al in the silicon iron were "good" as regards iron losses. The authors attribute the detrimental effect of aluminium to the formation of finely distributed aluminium oxide, which, because of its higher oxygen content, increases the iron losses.

Some manufacturers attach less importance to the aluminium or alumina content of the silicon iron and often add metallic aluminium deliberately to the melts. The transformer sheets obtained are in this case also completely satisfactory, but they are produced with different techniques, e.g., final annealing at a lower temperature in a hydrogen atmosphere. It is necessary for the composition and the technique to be suitably matched. This opinion was also expressed by F. Loos in an unpublished report on co-operative tests in different works.

The adverse influence of carbon was the subject of a report by Yensen and Ziegler[7] as early as 1935. However,

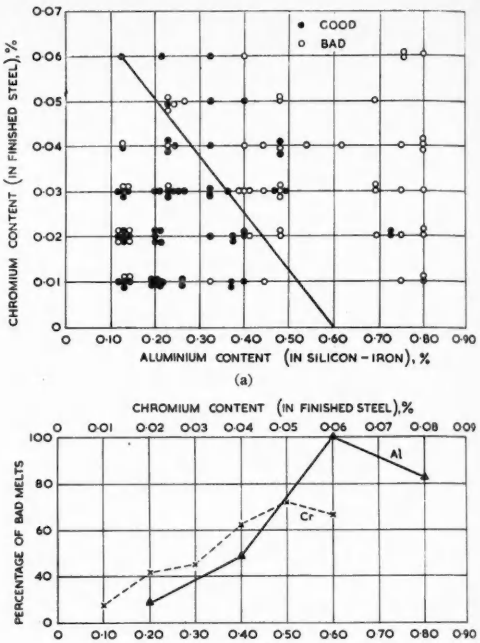

Fig. 1. **Influence on iron losses of the chromium and aluminium contents of silicon iron.**

these investigators did not find that oxygen produced an unfavourable effect in fields of less than 100 oersted. Their steel was melted in the laboratory from electrolytic iron and 98% silicon iron, using a high-frequency vacuum furnace and adding the oxygen in the form of iron oxide. The annealing operations were carried out in a hydrogen atmosphere or in vacuum. In contrast, in the present series of tests, the oxide was first formed during the annealing processes; as a result, it was more finely distributed and was therefore more effective.

Influence of the Melting Process

It is generally agreed that electric steel should be used to obtain the best results. Open-hearth melts, which have the same degree of purity according to analysis, give higher iron losses than electric steel. To determine the reasons for these differences, tests were carried out at the Capito and Klein works in 1933, in which investigations were made of decarburisation and oxygen absorption during working. Oxygen analyses of electric and open-hearth melts gave values of 0·002 to 0·004% oxygen in both cases, whereas in a preliminary test a semi-finished sheet of electric steel had 0·0013% oxygen and of open-hearth steel had 0·0022% oxygen. The annealed sheets contained 0·0014 and 0·0025% oxygen, respectively. The sheet bars were at that time still preheated in a furnace in which considerable decarburisation was obtained. The oxygen content of the electric steels in this process was increased to 0·0029-0·0041%, whereas that of the open-hearth steels was increased even more considerably to 0·0074-0·0097%. It would be useful if these tests could be repeated to-day on a larger scale, with the better analytical aids now available, to try to determine the reason for these differences. It might then be possible to avoid using electric steel to an even greater extent.

Experiments, in which electric and open-hearth steels were worked and decarburised as far as possible

in a hydrogen atmosphere, showed that, under such conditions, the differences in magnetic properties are hardly noticeable. They confirm, therefore, the above views. At the present time, open-hearth steel can yield favourable results, as, with 4·0 to 4·5% Si, L_{10} iron losses of less than 1·2 W/kg are definitely attainable.

Tests on basic Bessemer steel have also recently been made. The best result, obtained without using a protective gas atmosphere during annealing, was an L_{10} value of 1·1 W/kg. However, this steel seems to be even more sensitive to oxygen, perhaps owing to its aluminium content of 0·3%.

On the basis of an investigation made by Rushton and Davies[8] on a transformer steel with 4·2% Si, produced in an electric-arc furnace, differences in iron losses should be expected between various ingots obtained from the same melt, as well as at different positions in the ingot itself. The iron losses were higher in the first castings from the melt investigated, whereas in subsequent castings the non-metallic inclusions had sufficient time to rise into the slag. It is thus necessary to take a sufficiently large quantity of material into account for loss measurements, if reliable average values are to be obtained.

Influence of Rolling Conditions

The influence of rolling and annealing conditions was investigated by Delbart, Potaszkin, and Sage[9], in five-ton experimental melts containing 0·06-0·08% C, 3·1-4·0% Si, 0·04-0·13% Mn, and 0-1·6% Al. The results obtained, with L_{10} iron losses of 1·19-1·63 W/kg, were not favourable, perhaps because the final annealing termperature of 850° C was still too low. The ingots were soaked overnight at 1280-1320° C. The sheet bars were heated to 1050° C for 30 minutes and rolled out with two or three intermediate reheatings of 20 minutes each at 1050° C. The treatment with four heating operations gave better results than that with three heating operations, and this may be attributable to better decarburisation. The final rolling temperature should not be less than 750° C. The L_{10} and L_{15} iron losses do not always have the same ratio. It was also considered that the temperature at the end of the rolling process might also have some effect.

Vatchagandhy and Contractor[10] consider that the rolling temperature is not very important, although a final temperature of 700-750° C is mentioned as desirable. The difference in rolling temperatures can be counteracted by suitable annealing. This opinion was confirmed by the authors' experience.

In reorganising German mills the question considered was whether it would be possible to produce transformer sheet with modern walking-beam furnaces. This possibility could not have been considered in the years 1935-1936. In modern walking-beam furnaces, now used both for semi-finished bars and sheets, heating times have been very considerably reduced. The sheet bars are heated in these furnaces for about 45 minutes, and the heating times in the sheet-heating furnaces are about 20-25 min per operation, the rolling temperatures of the packs being around 950-1000° C. The output of these plants is very much higher than with the older methods. Furthermore, owing to the uniform heating, a more uniform thickness and a better surface are obtained, which also have an appreciable effect in the pickling and on the stacking factor. It was, however, necessary to increase the annealing times, in order to obtain sufficient decarburisation.

In the hot rolling of sheets, some thickness variation is always to be expected from the edges towards the centre. During subsequent annealing in stacks of 500 to 600 mm weighing about 4 tons, thickness variations cause the flat sheets to become rippled, particularly if annealed at high temperatures. Thus, it is extremely difficult to obtain flat hot-rolled sheets. The only possible remedy is the use of cold rolling, which eliminates thickness variations to a considerable extent. However, the cold working of high-silicon steel is very difficult and expensive.

Influence of Annealing

Iron losses are also considerably affected by annealing. Generally, it is indicated that the final annealing should take place at 850-900° C, and it is frequently pointed out that over-annealing occurs[10, 11].

On the basis of the authors' experience, it may be said that over-annealing can occur, but not necessarily. Evidence of this is given by a series of tests carried out on Epstein specimens of electric and basic Bessemer steel. The electric steel contained 0·04% C, 4·08% Si, 0·10% Mn, 0·007% P, and 0·007% S. The basic steel contained 0·02% C, 4·36% Si, 0·09% Mn, 0·022% P, 0·004% S, and 0·23% Al.

The losses for the electric steel were fairly high at the usual annealing temperatures of 800-900° C without a protective atmosphere, and satisfactory values were reached only from 950° to 1000° C, over-annealing not being observed. In contrast, the basic Bessemer steel attained satisfactory values at lower temperatures, and a marked deterioration (over-annealing) occurred at 1000° C. The different behaviour of these steels is attributable to the addition of aluminium in the basic steel, which probably absorbed more oxygen at the higher annealing temperatures, resulting in increased iron losses.

Over-annealing should not occur when annealing in a protective atmosphere. This was verified by annealing sheets of a basic Bessemer steel melt for 5 hours in hydrogen at 800°, 900°, and 1000° C. The L_{10} losses obtained were 0·98 W/kg at 800°, 0·95 at 900°, and 1·00 at 1000° C. Thus, very low iron losses were achieved at all annealing temperatures and no over-annealing was observed. In the authors' Works, high annealing temperatures around 1000° C have been used without a protective atmosphere for many years, without resulting in over-annealing of electric and open-hearth steels with a low aluminium content. Difficulties arise, however, owing to the tendency of the sheets to adhere to each other. This can, of course, be avoided by alumina or magnesia between the sheets, but in mass production this operation is an additional complication. Following Müller's suggestion[12], the procedure has been to stick tissue paper to the sheets; the paper burns during annealing, without causing any noticeable carburisation and the residual ash prevents an adhesion between the sheets. More recently, however, Engelhardt's method[12] has been employed :—Before annealing, the sheets are separated by a mixture of aluminium-magnesium silicate or oxide, to which an adhesive agent has been added. The quantity applied (by rubber rollers) is so minute that subsequent cleaning of the sheets is not necessary.

In American literature, procedures are indicated[13] for producing an insulating film of oxide on sheets. It is recommended that annealing be carried out in a hydrogen atmosphere at 500° C with slow cooling down to 300° C. However, a perfect oxide film will be formed only if the preceding high-temperature annealing operation has been performed in a reducing atmosphere. Furthermore, in a French patent of the Westinghouse Electric Corporation[11], details are given of a method using a magnesium-silicon preparation, as the insulating medium. Gould[15] describes a process by means of which a colloid of silica, for instance in acetone, is electrolytically deposited on a sheet. Tests made by the authors, however, showed that the insulating effect between the individual layers was no longer satisfactory with annealing between 1000° and 1200° C. Their own tests with phosphoric acid and phosphates showed that good insulation can be obtainable with phosphoric acid and phosphates. For instance, with a bonderising process, it was possible to obtain an insulating layer much thinner than paper insulation but just as effective, the breakdown value being 200 V. Even when annealing

at 800-850° C, this layer provides sufficient insulation in many cases. Small stampings can, therefore, be post-annealed to eliminate the deterioration during stamping. In the United States, details of a similar insulation, known as " Carlite," have been published.

Grain size, closely associated with annealing temperature, also affects the magnetic properties of transformer sheet. A coarse grain can be obtained by cold rolling, to give an increased length of about 4%[15a], but, according to a German patent[15b], this operation can be replaced by quenching at 1100° C. The conclusions of Vatchagandhy and Contractor[16], Yensen[16], and Rybalko and Yakutovich[17] indicate that a coarse grain is favourable and tnat, moreover, the grain structure is also of importance, elongated crystallites being more favourable than a polyhedral structure. In contrast, Michaud[18] was unable to find any influence exerted by grain size ; if anything, coarse grain seemed to be associated with high iron losses. While, however, it is substantially true that low losses are usually associated with a coarse grain, exceptions always occur. The experience of the authors is that the losses depend to a greater extent on the impurities (in particular, on finely distributed inclusions), and that generally, when the degree of purity is increased, coarse grains are also obtained. Greater importance should be attached to determining the influence of inclusions and additions. According to Kersten[19], it may also be expected that inclusions have a magnetic hardening effect.

The influence of hydrogen was investigated by Messkin and Margolin[20] in 1933. They found that with hydrogen the coercive force is increased. Although the hydrogen is completely released when annealing above 800° C, an embrittlement was, however, observed. This was probably due to the formation of methane or water vapour, which cause cracks. However, under normal annealing conditions, there is no deterioration in magnetic properties from hydrogen absorption. Annealing is frequently carried out in a hydrogen atmosphere, to eliminate the detrimental effects of carbon. Although the addition of steam usually accelerates decarburisation, it was found by Awerbusch and Tschufarow[21] to have an opposite effect in the case of pickled transformer steel, because a thin film of SiO_2, and possibly of iron silicate, had formed on the sheet. Decarburisation is also less effective in mixtures of hydrogen and nitrogen, as a result of the reduced partial pressure of the hydrogen. Presumably, the phenomenon depends on the speed of reaction of the carbon with hydrogen, and not on the rate of diffusion. Working with pure hydrogen at 1000° C, and even higher, is recommended ; the hydrogen should be blown through the furnace at a high speed, to remove the methane produced in the process.

In addition to iron losses, associated coercive forces are important. Messkin regarded as favourable a coercive force of 0·33 oersted with an iron loss of 1·0 W/kg for a melt decarburised by means of hydrogen to 0·03%. Strauss, Stäblein, and Meyer[22] obtained coercive forces between 0·1 and 0·3 oersted in large-scale tests, the decarburisation being obtained by annealing in hydrogen. Investigations were also carried out on silicon-iron alloys by Yensen and Ziegler[7], who consider the sulphur content to have a less adverse effect than carbon, the latter increasing the coercive force, particularly when it is in solution and in the form of pearlite. With silicon contents greater than approximately 4%, carbon separates out in the form of graphite, which reduces magnetic properties only to a slight extent.

Permeability is another important property to be considered. In general, it may be said that permeability increases with decreasing iron losses. For instance, tests by the authors showed that specimens with a loss of 1·2-1·3 W/kg with 0·02 oersted had permeability values between 242 and 656, whereas sheets with a loss of 0·98-1·11 W/kg had permeabilities between 748 and 1245. Admittedly, these differences were abnormally high. However, although average values can be indicated, exceptions continually occur, so that it is not at all certain that a sheet with a loss of 0·9 W/kg will correspond, for instance, to a permeability μ_{20} of not less than 700 at 0·02 oersted. Investigations by the authors on silicon iron containing less than 0·4% Al indicated that a low calcium content gives improved permeability, μ_{20}-values between 1000 and 1590 being obtained in most cases. These results, however, require further confirmation. Materials with an aluminium content greater than 0·4% gave a reduced permeability, even with low calcium contents, μ_{20}-values being between 600 and 1000. Goldmann and Grechow[23] obtained initial permeabilities of up to 1000 after a six-hour annealing at 1100° C in a hydrogen atmosphere. According to the authors' experience, it is possible to produce sheets with guaranteed permeabilities of not less than 1200, or even 1500 (at 0·02 oersted), using very careful manufacturing techniques and reducing the carbon content to less than 0·01%. Pawlek[21] was able to obtain initial permeabilities of 2000 by annealing in hydrogen at 1300° C.

It should be noted that Fahlenbrach and Sixtus[25] found that the previous magnetic history of a material also has an influence on measured results. Some caution is therefore advisable in comparing the results of different investigators. Moreover, it should also be mentioned that the bending ability (which is frequently a major factor in stamping operations) decreases with increasing silicon content ; thus, it is inadvisable to exceed 4·5% Si. Crystal formation also has an influence. High-temperature annealing of transformer steel containing more than 4% Si can also have an adverse effect on bending ability, owing to the coarser grain and also to the absorption of hydrogen.

(To be concluded).

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(13) P. L. SCHMIDT : *Mater. & Meth.*, Vol. 29, 1949, No. 4, pp. 54-56 ; W. MORRILL : *Metal Prog.*, Vol. 54, 1948, pp. 675-678.
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(16) *J. Appl. Phys.*, Vol. 16, 1945, pp. 379-385 ; and *Chem. Zbl.* (r.), Vol. 120, 1949, Pt. I, pp. 1031-1032.
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(19) *Phys. Zeits.*, Vol. 44, 1943, pp. 63-77 ; M. KERSTEN : " Basic principles of a theory of magnetic hysteresis and coercive force " (in German). Leipzig, 1943.
(20) *Metals & Alloys*, Vol. 10, 1939, pp. 26-31 ; *Arch. Eisenhüttenw.*, Vol. 6, 1932-1933, pp. 399-405 ; *Stahl u. Eisen*, Vol. 53, 1933, p. 308.
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(23) *Uralskaja Metallurgija*, Vol. 9, 1940, No. 11/12, pp. 24-26.
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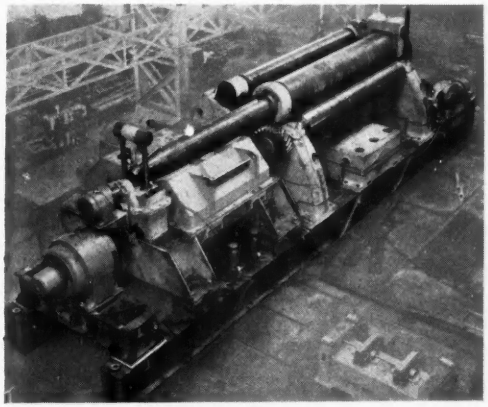
New Materials, Processes and Equipment

PLATE-BENDING AND STRAIGHTENING MACHINE

A heavy-duty plate-bending and straightening machine, which is probably the largest machine of its type to have been produced in Great Britain, has recently been designed and built by Joshua Bigwood & Son Limited, of Wolverhampton. This machine is intended to fulfil the requirements of those fabricating shops which do not have a sufficiently large output to justify the installation of separate machines for levelling and for curving plates.

The machine has three rolls arranged in pyramid, which are used in the usual way for rolling plates to cylindrical or conical forms; in addition, there is a fourth roll, which can quickly be set into a position in which it converts the machine into a 4-roll leveller. All movements are motorised, and may be controlled from a single point, remote from the machine.



The rolls are machined from high-carbon steel forgings; the housings are heavy steel castings and carry the two bottom rolls in large phosphor-bronze sleeve bearings. Chocks, working in slides machined in the housings between the lower roll-bearings and secured by thrust pins to heavy adjusting screws, carry the top roll. The worm and wormwheel nut and heavy-duty roller thrust bearing, forming the top-roll adjusting gear, are enclosed in the housing castings and are driven through reduction gearing by a 50-hp electric motor.

The main drive is by a 110-hp motor of the slip-ring type, connected through a Bibby-type coupling to the main gearbox. This gearbox is of heavy steel fabrication and contains double helical steel gears. The gearbox is sectionalised for lubrication purposes, the high-speed section being lubricated by oil bath and the low-speed section by pump feed.

The top roll is extended to terminate in a ball end under a swivelling yoke, which forms part of the jacking screw mechanism used to balance the weight of the top roll and so relieve the pressure on the outer bearing when its housing is swung clear of the machine to make possible the removal of closed circular forms from the rolls. This bearing housing, the weight of which is counterbalanced, is swung by levers and quadrant and pinion gearing, motive power being provided by an electric motor, driving through a slipping clutch. An air-operated clutch is included in the drive for top-roll vertical adjustment, and when this is disengaged, the inner end of the roll can be moved independently of the outer end; thus, the top roll can be tilted, in order to bend plates into conical forms.

Electric interlocks and limit switches are provided as a protection against the possible over-running of all motorised movements. The four motor controllers, air control valves, indicating dials, etc., are located on a control desk, so that a single operator can exercise complete control from one point. Two centralised "Farvalube" lubricating systems are incorporated, to ensure the effective lubrication of all bearing points.

Similar dual-purpose machines, with an additional straightening roll for 5-roll levelling, are also manufactured by the Company.

BOLT-THREADING MACHINE

Intended primarily for production work on all forms of parallel threads, the type PR bolt-threading machines, manufactured by Maiden & Co. Ltd., of Hyde, Cheshire, are available in 1-in. and 1¼-in. sizes, with either radial- or tangential-type die heads.

The design of the radial-type die head, which controls the adjustment and release and close of the dies, is of special interest. Angular slots are cut in the cam, to control the movement of the die blocks; when the hand lever or automatic release is operated, the die blocks, in which the tools are held, move along the slots and withdraw the dies from the work In those instances where tangential-type die heads are required, the Lanco or Wagner unit is normally adopted, depending upon the work and the capacity for which the machine is required; however, it is usually possible to accommodate the needs of those who have standardised on other makes of tangential die head and wish to continue the same policy.

The machine incorporates two essential features which can be operated whilst it is in motion, i.e., micrometer adjustment to the dies, and a double-cut arrangement which simplifies threading where an exceptionally heavy cut or an extra-fine finish is required. This mechanism is controlled by a convenient lever, eliminating the need to reset the dies before performing the second cut.

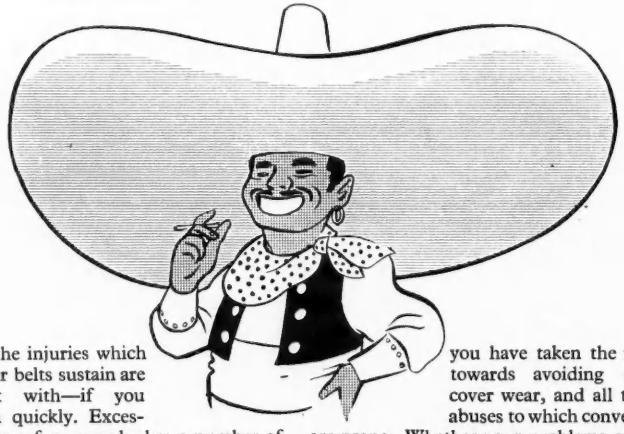
A feature of the machine is a multi-disc friction clutch, controlling the application of power to the spindle from a continuously running motor. Apart from the safety factor enabling the rotation of the spindle

PRACTICAL BELTMANSHIP ILLUSTRATED

CARE OF BELTS

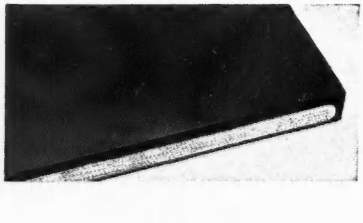
No. 5

"Excessive Cover Wear"



MOST of the injuries which conveyor belts sustain are easily dealt with—if you 'catch' them quickly. Excessive cover wear, for example, has a number of easily remedied causes, but unless prompt action is taken you may shorten the life of a belt considerably. Correct installation and regular maintenance will greatly increase the life of belting—and you'll find out all you want to know about its care in the Goodyear Maintenance Manual. When you specify Goodyear you have taken the first step towards avoiding excessive cover wear, and all the other abuses to which conveyor belts are prone. Whether your problems arise from abrasion, heat, load, lift, speed or troughing, Goodyear can help you!

The Goodyear Maintenance Manual is a very helpful 32-page booklet that is issued free on request. Please write to Dept. K.5, Goodyear Tyre & Rubber Co. (G.B.) Ltd., Wolverhampton, for your copy.



GOODYEAR
"STACKER" CONVEYOR BELTING

Ideal for conveying ores of all kinds, rock, granite, glass cullet and materials of a similarly highly abrasive nature. Treated against mildew. It has the toughest covers obtainable, with the greatest possible resistance to cutting, gouging and abrasion. Available in a full range of plies and gauges, it is well suited to high temperatures and abrasive conditions.

GOODYEAR

INDUSTRIAL RUBBER PRODUCTS

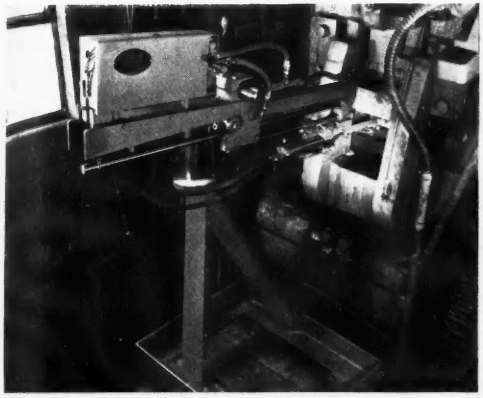
TRANSMISSION BELTING · V-BELTS · CONVEYOR BELTING · INDUSTRIAL HOSE

to be discontinued and stopped immediately with the assistance of the brake incorporated within the same unit, this unit permits continuous running of the motor, thereby eliminating the frequent use of the starter. Furthermore, it lends itself to the more rapid centering of work, to earlier commencement of threading, and to die-head inching for setting-up purposes. The combination of these features accounts for a substantial reduction in non-productive handling time.

The saddle is of robust construction and is fitted with self-centering jaws, operated by left- and right-hand threads. Hardened steel grips are provided for the gripping of bright drawn and black mild steel, and special holders can be obtained for a variety of other work. The traverse of the saddle is by rack and pinion.

PORTABLE AUTOMATIC UNLOADER

As companion equipment to its line of swinging-arm type automatic unloaders, the Sahlin Engineering Company, of Birmingham, Michigan, has introduced a new portable unloader (portable " Iron Hand "), which can be wheeled up to small and medium-size presses for the automatic removal of small parts.



The machine, which consists of jaw, air-cylinder, and electric-control assemblies similar to those used in the original " Iron Hands," can be adjusted to reach various die levels and can be set at any angle required. Jaw travel is in a straight line, and is especially suitable for the removal of small parts at high speed. Owing to its portability, high speed, and safety features, the new unloader is expected to find wide usage on applications where it is impractical to eject parts mechanically, or through a bed opening or by gravity.

The unloader is mounted on a heavy steel frame, which rides on four caster-type wheels. A built-in locking device is provided. Because the machine is mobile, it is particularly suitable for job-shop work or for short runs, as it can be kept in continuous service by moving it from one press to another.

Operation of the new unloader is as follows :— When the ram descends and completes the forming or shearing operation, the steel jaw moves into the die and takes a firm hold on the stamping, as soon as the ram rises sufficiently. The jaw lifts the stamping, moves back out of the die, and drops the stamping into a tote-box or onto a conveyor. It then returns to its original position to await the next cycle.

Jaw designs of various types are available for a variety of special unloading conditions. These include a hook type for application where a gripping edge is lacking ; a neoprene-tipped grip, to protect parts with special finishes ; a pivot type, which can be swivelled laterally to clear tight die areas ; and a confined type, which locks a vertical flange stamping without damaging the edges.

GAS-TURBINE-DRIVEN FIRE PUMP

Production of a new, ultra-lightweight fire pump, powered by a gas turbine, is announced by Sigmund Pumps Limited, of Team Valley, Gateshead. Designated the Sigmund Rover 1S/60, the complete pumping set consists of a Rover gas turbine and a specially designed Sigmund centrifugal pump, close-coupled to the power unit. The whole assembly is mounted in a lightweight tubular frame, complete with fuel tank and a fully instrumented panel, for easy portability.

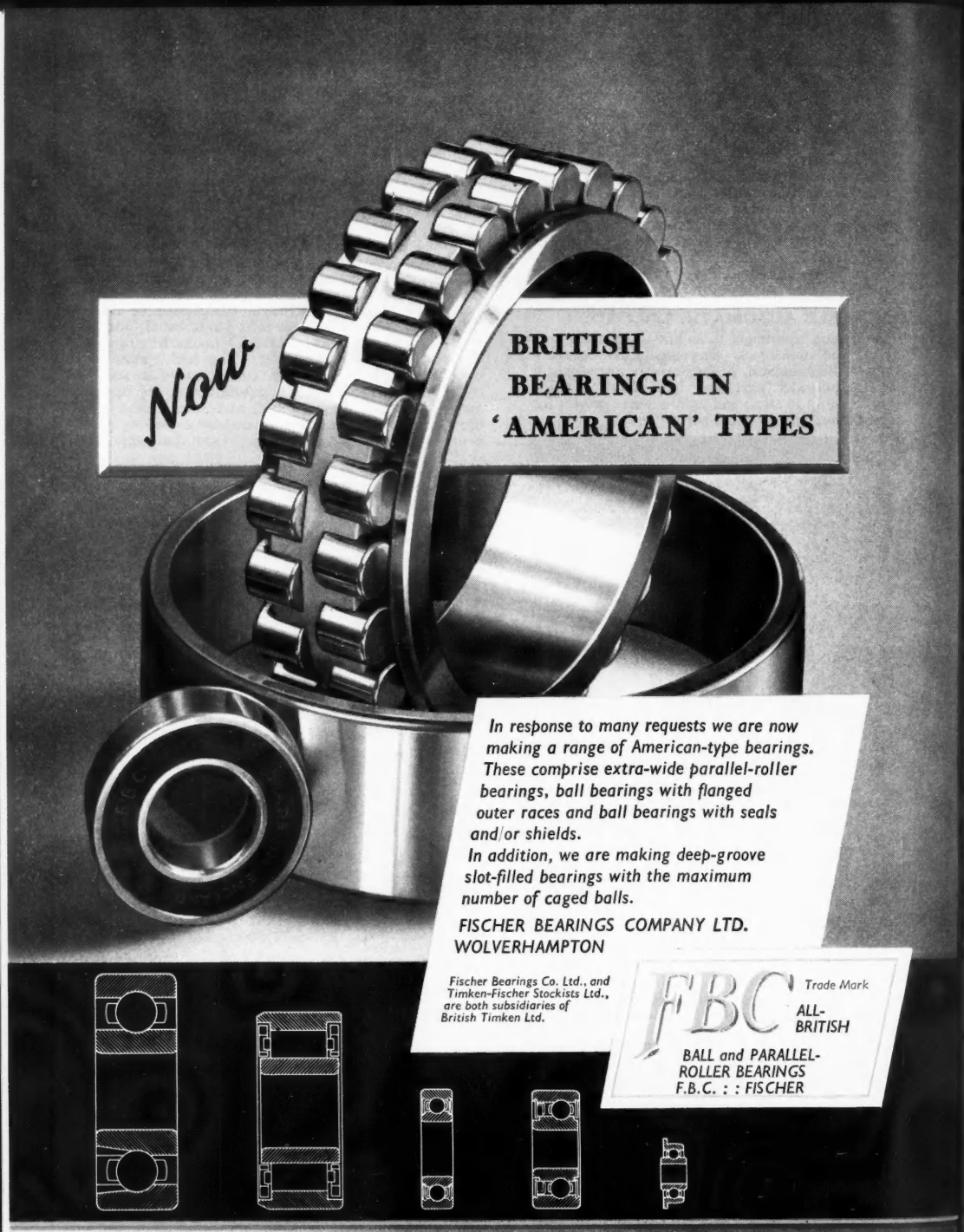
The power unit is a single-shaft gas turbine, with a continuous rating of 60 shp at a turbine-rotor speed of 46,000 rpm. Power is taken from the compressor shaft through suitable reduction gearing to drive the water pump at 4500 rpm. The main components of the unit are the single-stage centrifugal compressor of forged aluminium alloy, with steel inlet guide vanes, and the axial-flow turbine, machined from Nimonic forging, with blades integral with the disc. The fuel system and governor are self-contained, consisting of a starting control, accelerator control, maximum speed control, maximum temperature control, and a fuel filter. The unit, which is attached to the auxiliary mounting plate, is driven through a reduction gear from the compressor shaft.

The lubrication system consists of a gear-type oil pump submerged in the oil sump formed in the base of the compressor housing. Two filters are incorporated in the system, a suction filter to protect the pump gears from ingress of foreign matter and a " Purolator " micro-filter on the discharge side of the pump. Provision for oil cooling is made in the oil sump.

A high heat-release combustion chamber is used, incorporating either a spill-type burner or a variable-flow pressure-sensitive type of burner.

The fuel consumption is 1·4 lb/bhp-hr at the continuous rated condition. Air flow is 1·35 lb/sec and the jet-pipe temperature is 600° C.

The pump unit incorporates a specially designed single-stage centrifugal pump, with a capacity of 400 gpm at a total delivery head of 231 ft when pumping from a 10-ft static lift, using three lengths of 4-in.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In response to many requests we are now making a range of American-type bearings. These comprise extra-wide parallel-roller bearings, ball bearings with flanged outer races and ball bearings with seals and/or shields.
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BALL and PARALLEL-ROLLER BEARINGS
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smooth-bore suction hose and a strainer. The suction eye is provided with a standard 4-in. suction hose connection, with removable internal strainer and blank cap, whilst on the delivery side two 2½-in. delivery valves of approved type, with standard hose connections, are provided.

Drive for the pump is taken from a gear wheel fitted on splines and supported in a double-row conical roller bearing lubricated by pressurised oil from the turbine, this oil being injected into the bearings through a hollow shaft and returned *via* the gear casing to the turbine oil sump. The bearing housing and gear chamber form part of the liquid space of the pump and are thus cooled by the liquid pumped. A plug is provided on the pump casing for the purpose of taking off cooling water, if required. A mechanical seal is used for sealing the stuffing box, liquid collecting in the chamber between oil seal and mechanical seal being taken away through the drain hole. The priming unit consists of an air ejector, which takes the air for this purpose from the compressed air receiver of the gas turbine. This is operated by a single lever and is designed to lift water 24 ft at the rate of not less than 1 fps at atmospheric pressure.

Hand-starting is by means of a cranked handle connected by sprockets and a chain to the oil-pump driving gear, which operates the compressor shaft *via* the intermediate gear of the auxiliaries' driving gear train. Operated in conjunction with the starting mechanism is an electric generator, which provides the high-energy spark to ignite the mixture in the combustion chamber.

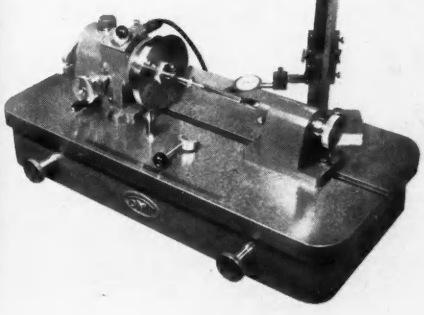
A fuel tank, with sufficient capacity for 25 minutes operation, is secured within the frame by means of metal straps, and an instrument panel positioned above the water pump is bolted to the tubular frame. Carrying handles, which fold down when not in use, are attached to the front and rear struts of the tubular frame. As an alternative, the whole unit can be mounted on a specially designed trailer of welded construction.

The unit can be run on commercial petrol, commercial paraffin, diesel fuel, or any distillate fuel.

OPTICAL DIVIDING HEAD

A new instrument, the O.M.T. Optical Dividing Head OW7, designed primarily for inspection and light machining purposes, is announced by Newall Group Sales Ltd., of Peterborough.

The back face of this instrument is truly flat and square to the axis, so that the head may be used with the spindle in the horizontal or vertical plane. The eyepiece is easily accessible in either position and the optical scale reads direct to one minute. For coarse adjustment, an external scale ring is provided close to the eyepiece. Rotation is effected by a handwheel through a worm and wormwheel, which can be disengaged for rapid positioning simply by the movement of a lever. A positive non-deflecting locking device is also incorporated and is operated by a knurled knob adjacent to the eyepiece. Illumination is by a 12-V, 3-W lighting unit which is fed from the mains through a small transformer.



Work can be held either in collets or between centres, and a face plate can also be provided. Included in the equipment is a tailstock and a baseplate, which is sufficiently large to accommodate clock stands, height gauges, etc.

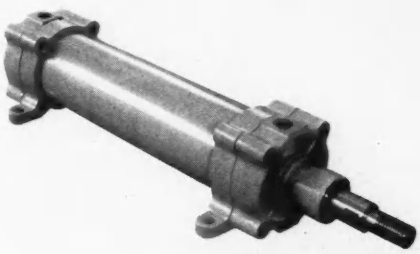
The illustration shows the dividing head with tailstock and baseplate in use for inspection purposes.

COMPRESSED-AIR CYLINDERS

An entirely new range of compressed air devices, including cylinders and control valves, has been introduced by the Pneumatic Division of Baldwin Instrument Co. Ltd., of Dartford, Kent.

At the present stage of development, air cylinders from 1½ to 6-in. bore are in regular production, together with a full range of directional control valves in ⅛-, ¼-, and ½-in. bore sizes.

All standard air cylinders are fitted with precision-drawn steel barrels, which are hard chrome plated and polished in the bore. This ensures freedom from corrosion troubles from suspended moisture in the air supply, and provides a very hard and highly finished surface. Piston rods are made from precision-ground stainless-steel bar, which is subsequently polished, to keep bearing friction and seal wear to a minimum. A tough synthetic rubber wiper is fitted in all cases, to remove any gritty impurities which may be deposited on the rod when in the extended position.



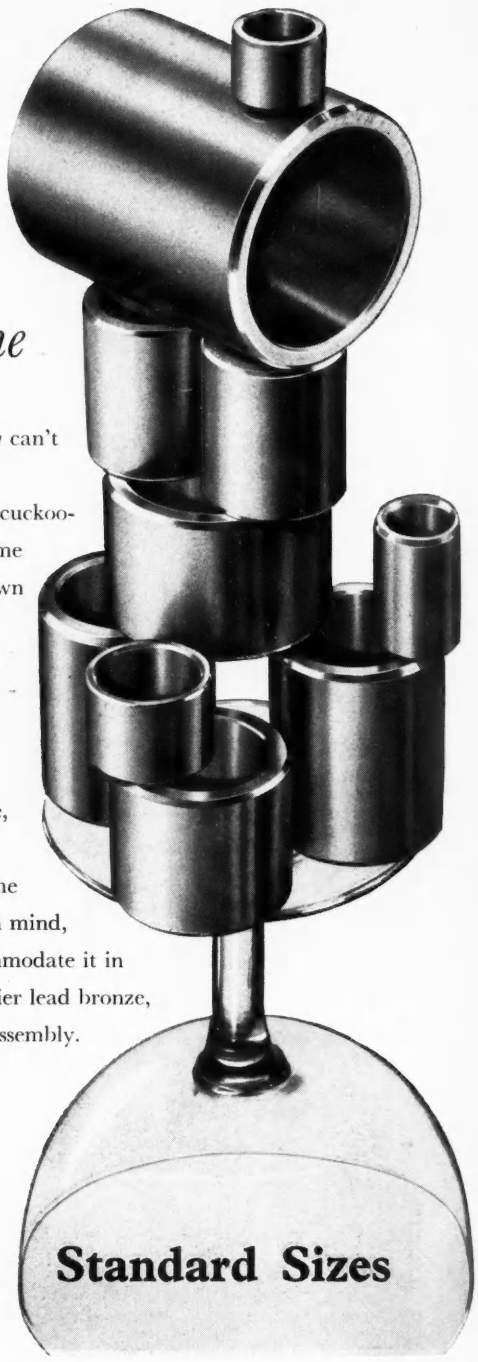
Oil- and water-resisting synthetic rubber seals are used exclusively; these are of the fully dynamic type, thus compensating automatically for wear and air-pressure variation. Full protection against corrosion of ferrous components is obtained either by electrolytic plating or by the use of a special zinc diffusion process.

Cylinders in all bore sizes are available with a built-in cushion feature of improved design, at either or both ends of the stroke, according to the requirements of each application. Also, the piston rod may emerge from one end cover only, or it may pass completely through the axis of the unit and emerge from both end covers.

Seven different forms of standard mounting are available for each style and bore size, i.e., basic, foot, front pedestal, rear pedestal, front trunnion, centre trunnion, and rear trunnion. Thus, 280 standard types are offered, to suit exactly the requirements of most applications.

As shown in the accompanying illustration of a standard 3-in. bore double-acting cylinder, a unit system of construction is employed. This gives a clean appearance and simplifies the work of installation and maintenance, as the end cover assemblies can be removed separately without disturbing the mountings in most cases. Also, the supply ports can be re-positioned on site to any more convenient position by loosening the four screws, and rotating the end covers.

A good bush needs no wine



A good bush lacks nothing that a little *standardisation* can't give it. Once upon a time (like, alas, many British manufacturers) we ourselves lived in a sort of cloud-cuckoo-land . . . waiting until each totally new order, in some totally new bastard size, provoked us into laying down the tooling, patterns, etc., to carry it out.

That was long ago. We came to our senses. Now we have a full STANDARD range of bronze bushes which we hold in stock, ready for immediate delivery. There are 191 of them in perfect series, graduating in length, nominal bore and housing size, plus five standard groovings.

Never mind the man who can pay for any caper he pleases. All *you* have to do, with time and money in mind, is to choose the nearest Glacier Standard and accommodate it in your design. We deliver, finished and ready, in Glacier lead bronze, with an allowance in the bore for final sizing after assembly.

Whether it's bronze bushes, wrapped bushes or bronze bars, that's the logic behind . . .

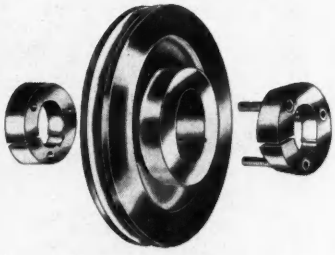
GLACIER
REGD. TRADE MARK

Standard Sizes

THE GLACIER METAL COMPANY LIMITED, ALPERTON, WEMBLEY, MIDDLESEX

TAPER-LOCKING PULLEY

Manufactured by Zerny Engineering Co. Ltd., of London, N.W.3, " Dualok " is a new, patented, twin-grip, taper-locking pulley. It is outstanding in that, as shown in the illustration, it is fitted with twin taper bushes, which uniformly grip the shaft with such a powerful wedging action that a torque of 400 lb-ft is required to shift the smallest " Dualok " hub, fitted without a keyway. This is equivalent to 75 hp at 1000 rpm.



The "Dualok" costs little more than an ordinary keyed-on pulley and interchangeable bushes are supplied in all standard sizes from $\frac{1}{2}$-in. to 4-in. diameter shaft, and up to 42 in. P.D.C., with $\frac{1}{8}$-in. grooves. No keyway is necessary, and the pulley can be speedily fitted or withdrawn by unskilled labour. The bushes fit flush with both sides of the pulley, giving neatness and, above all, safety. The " Dualok " hub can also be used in chain wheels, gear wheels, flat pulleys, and special applications.

INDUCTION MOTORS

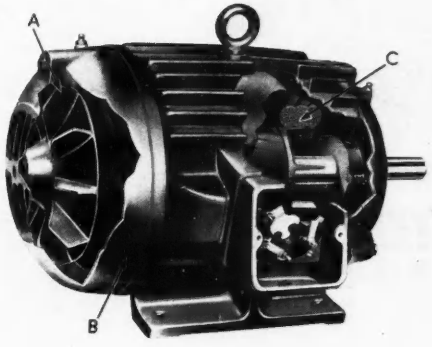
A range of squirrel-cage induction motors, specially designed for operation in the corrosive, but non-explosive, atmospheres found in installations such as chemical plants, plating shops, gas works, coke plants, salt works, and oil refineries, is now being manufactured by The English Electric Company Limited, of Stafford. These motors are made to British Standard dimensions and are available in outputs up to 25 hp; although similar in appearance to the normal " English Electric " class LY, totally enclosed, fan-cooled motors, they incorporate many corrosion-resistant features.

A moulded plastic fan, mounted on the non-driving end of the shaft, cools the motor by blowing air along axial cooling fins, integrally cast with the motor frame. The fan is made from phenol formaldehyde, and durability and fatigue tests have been successfully carried out to prove the suitability of this material and also the special method of fixing the fan on the shaft.

Polyvinyl-acetal-covered wire is used for the stator winding. The windings are impregnated with phenolic insulating varnish by dipping and baking them four times in an automatic, heat-controlled continuous oven; this process has been found to produce a finished winding capable of high resistance to corrosive chemicals.

Wherever possible, cast iron is used for components forming the external surfaces of the motors. The cowl over the fan is also made of cast iron instead of pressed-steel, and all external surfaces of the stator and the fan cowl are finished with a special protective paint.

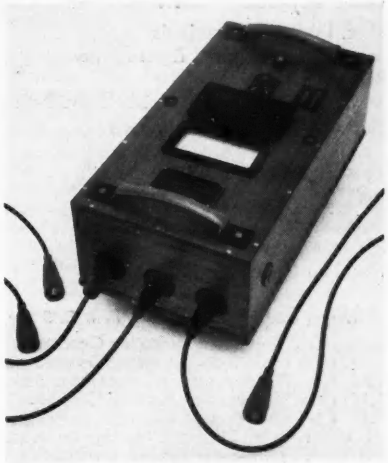
The accompanying cut-away view of the motor shows the moulded plastic fan (*A*), the cast-iron fan cowl (*B*), and the corrosion-resistant winding (*C*).



10,000-V, MAINS-OPERATED INSULATION TESTER

Some of the more recent requirements of insulation testing demand that the test be continued for periods of up to thirty minutes and even more. Such tests, using hand-driven instruments, are impractical, especially with the higher-voltage instruments, where the turning effort is necessarily heavy.

To meet these cases, a 10,000-V, mains-operated insulation tester has been produced by Evershed and Vignoles Limited, of Chiswick, London, W.4, in which the hand generator has been replaced by a static rectifier operating from a.c. mains through a step-up transformer. This instrument, which has the highest testing pressure so far produced in the " Megger " range, is of the true ohmmeter type and gives a direct indication of the value of the insulation under test, without adjustments or calculations of any kind.



The dial, which is located on top of the instrument, has two scales, the outer scale having a range of 60 to 200,000 megohms and infinity, and the inner scale a range of from zero to 1000 megohms. Adjacent to the dial is a range switch, by means of which the inner or outer scales can be selected. In addition, a red pilot lamp, so located on top of the instrument as to be visible from all directions, is provided, to indicate when the instrument is in operation.

The mains plug socket and the mains control switch are mounted on one end of the instrument case; the plug is of the " latch " type, which cannot be withdrawn accidentally. The opposite end of the case carries the line, earth, and guard terminals, which take the form of plug sockets.

The instrument case is constructed of well-seasoned teak and is 23 in. × 12 in. × 10½ in. in height. The complete instrument (without leads) weighs approximately 54 lb, and is mounted on three substantial levelling feet, a spirit level being fitted in the instrument dial.

PHILIPS INDUSTRIAL HIGH FREQUENCY HEATING EQUIPMENT

Philips Electrical Limited manufacture a wide range of High Frequency Generators and allied equipment for Induction and Dielectric heating applications, ranging, in the case of Induction heating, from the large 160 kW. generator down to one of only 2½ kW. Philips extensive experience in many branches of industry has been utilized in the design and construction of these generators. Three popular models are described below:

F.280 (160 kW) Generator :

Max. Power output at terminals	160 kW	Cont
Max. Power required from Mains	300	kVA
Power Factor	0.9	
Mains Supply Voltage — 380/440v. 3-ph	50	cycles
Nominal Frequency	200	kc/s

F.50 (25 kW) Generator :

Max. Power at Terminals	25	kW
Max. Power required from Mains	50	kVA
Power Factor	0.9	
Mains Supply Voltage — 380/440v. 3-ph	50	cycles
Nominal Operating Frequency	350	kc/s

F.5 (2½ kW) Generator :

Max. Power at Terminals	2½	kW
Max. Power required from Mains	5	kVA
Power Factor	.85	
Nominal Operating Frequency	520	kc/s

Other Philips Generators available are :—

F.150 (80 kW) Induction Heating Generator
F.100 (50 kW) Induction Heating Generator
F.26 (14 kW) Induction Heating Generator
F.18 (10 kW) Induction Heating Generator
F.13 (6 kW) Induction Heating Generator
DF.1500 (750 W) Dielectric Heating Generator
DF.6 (3 kW) Dielectric Heating Generator.
All the above generators conform to BSS. 1799.

PHILIPS also manufacture a range of allied equipment including Work Inductors and Concentrators, Flexible Water Cooled H.F. Leads, H.F. Change-over Switches, and Melting Units. For full information, please write to the address below.

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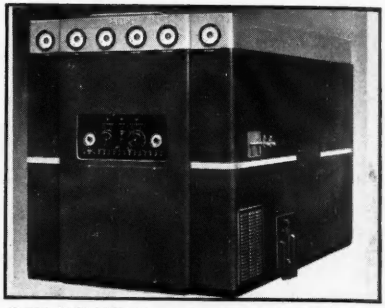

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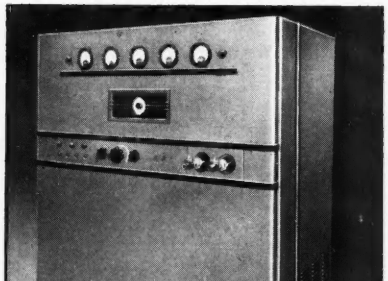

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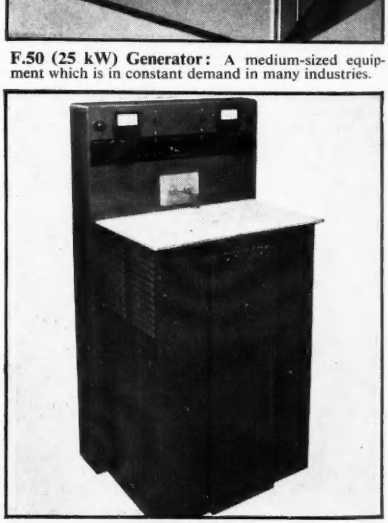

F.5 (2½ kW) Generator: Compact and extremely versatile, this low-powered equipment has proved increasingly popular.

(HF271)

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

DUST CONTROL

The Observation and Control of Dust at Portable Abrasive Wheels and Pneumatic Chisels.

By A. T. HOLMAN, E. B. JAMES, and W. B. LAWRIE. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, April 9, 1954, 12 pages, 23 illustrations.)

THE main features of a portable machine are lightness and a certain neatness of design which makes for flexibility. In the development of a dust-control system for such a machine, certain features are desirable :—The dust-control system should form an integral part of the machine, so that there would be no temptation to use the machine without it ; the system should be designed as an inconspicuous part of the machine ; very little additional weight should be tolerated ; and the machine should retain its flexibility.

This paper describes a new form of dust control for portable grinders. The method has been developed on a study of the aerodynamics of the system, as shown by motion pictures of the moving dust clouds produced when grinding. It was known from earlier work that the dust in the respirable size range does not follow the sparks thrown off by a grinding wheel. As a result, the present work, which represents the first attempt to control dust through the portable wheel-guard, was directed to the control of dust in the respirable size range. Still photographs of the dust clouds are included in the paper.

For many years, pneumatic chisels have been used without any method of dust control, although an increasing volume of medical evidence has shown that these tools produce dangerous dust in certain industries. In some cases, stone-masons have fitted small local exhaust ventilation hoods in front of the chisel, and a recent paper has described an exhausted dressing bench for use in steel foundries. There are, however, many instances where the work cannot easily be placed on such a bench. Hence, a new dust-control system has been fitted to a pneumatic chisel. In this design, local exhaust ventilation is applied through a hollow chisel, and the dust is extracted through the pneumatic hammer.

The main effort has been directed to the control of dust within the respirable size range, and the whole system was evolved as a result of the observation of the paths taken by the airborne dust produced by chipping. The moving dust clouds observed during the development stages have been photographed by a motion-picture camera, and the paper includes still photographs taken from the 35-mm film negative.

GEAR DRIVES

Non-Circular Cylindrical Gears.

By U. OLSSON. (From *Acta Polytechnica, Sweden*, Mechanical Engineering Series, Vol. 2, No. 10, 1953, 228 pages, 71 illustrations.)

CYLINDRICAL gears may be constructed not only with circular wheels but also with wheels of other shapes. Indeed, it is possible to construct such gears with one of the wheels of any desired shape. The sole essential condition is that, if the pitch curves or rolling curves of the wheels roll on each other without slipping, then the distance between the axes of rotation should be constant. Quite a number of the common mathematical curves, such as the circle, the ellipse, and the logarithmic spiral, possess this property. Mention must also be made of the hyperbola with the axis of rotation in one focus ; two such equal hyperbolas can roll on each other with constant distance between the axes of rotation.

Of the above-mentioned curves, only the ellipse has the property generally required of a rolling curve for gears, i.e., that it shall be a single-turn closed curve. When two hyperbolas roll on each other, it is true that, after a rotation of 360 deg., one returns to the starting point, and from this point of view they are applicable as rolling curves (pitch curves) for gears ; however, in this case the point of contact moves out to infinity, so that they are useless for gears which must rotate and where a gear segment only will not suffice. The same is the case with the other non-closed gears.

The author of this work presents a method for designing, with whatever degree of accuracy required, non-cylindrical gears of any shape. After a survey of the general laws for non-circular gears, he deals with conic section curves, choosing one of the foci as the axis of rotation, and then determines the mating curves to these, with varying distances between the axes of rotation. The latter curves are called conic-section rolling curves.

The pitch curve for an arbitrary wheel can be composed of arcs of such conic-section rolling curves. The given curve is then divided into a convenient number of arcs, and each arc is replaced by an arch of a conic-section rolling curve in such a way that the two end radii, as well as the slope of the curve to these radii, will be unaltered. Formulae for finding the substitute arcs are deduced. In addition, formulae are developed for determining the pitch curve of the mating wheel, which also will consist of arcs of conic-section rolling curves. Finally, methods of performing tooth cutting of non-circular gears are described.

MARINE ENGINEERING

Friction and Form Resistance in Turbulent Flow and a Proposed Formulation for use in Model and Ship Correlation.

By G. HUGHES. (From a paper presented at a meeting of the *Institution of Naval Architects, London*, April 9, 1954, 28 pages, 21 illustrations.)

THIS paper gives the results of additional experiments on the friction resistance of smooth plane surfaces in turbulent flow. The work covers a range of length/breadth ratios of the surfaces from nearly zero to 64. Submerged plates and sheets and shallow-draught pontoons were used.

It is shown that these results conform to a skin-friction formulation represented by a family of lines of specific resistance to base Reynolds number. The basic line is for infinite aspect ratio, or two-dimensional flow without edge effect. The lines for other values of the length/breadth ratio are at constant percentages above the basic line. Formulae for the basic lines are given. Some results of experiments with submerged cylinders are also given. These show that the effect of transverse curvature is to make the slopes of the friction lines steeper than for plane flow.

The application of this work to hull resistance is considered. From the results of a number of model hull tests at low speeds, it is concluded that form resistance also varies with Reynolds number as a constant percentage of the basic plane friction resistance, similarly

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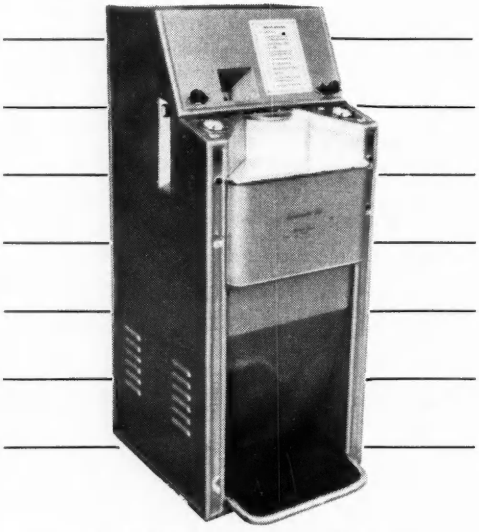

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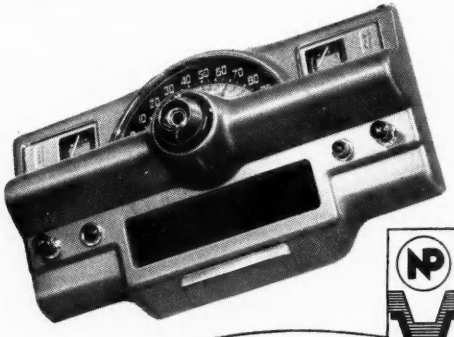

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to the edge effect of plane rectangular surfaces. A universal law to this effect is stated.

Model and ship correlation, using the proposed formulation, is discussed, and comparisons are made with the Froude and Schoenherr methods.

One of the most interesting conclusions from this work is that the hull resistance of the ideally smooth ship is much less than has hitherto been supposed. It is doubtful whether the very best results yet achieved on trials are within reach of the best possible result, and it is possible that this will not be effected without a special covering to the hull surface, similar to the plastic used in the model tests. If this can be achieved, the problem is solved, as such a plastic covering would be waterproof, durable, and smooth, and would not require any painting. There is no doubt that, if such a surface could be provided and retained in service, the economic advantages would be very considerable.

MATERIALS TESTING

Practical Aspects of Hardness Tests for Strip Steel.

By G. MOLINDER. (From *Jernkontorets Annaler, Sweden*, Vol. 138, No. 2, 1954, pp. 81-96, 12 illustrations.)

IN this article a method is described for hardness testing on a cross-section of strip steel by the Vickers method (with a " square " or Knoop indenter). In this connection it is emphasised that hardness testing of hardened strip steel should always be made on a cross-section of the strip to give reliable results and that the Vickers method is the only one which has sufficient accuracy and which is sufficiently flexible to be used for such testing. Furthermore, this method has the additional advantage over all other testing methods in that one hardness scale only can be used for all hardnesses ranging from that of annealed soft iron to that of hardened untempered high-carbon steel.

When carrying out hardness tests against the surface of a strip with Vickers or Rockwell, inaccurate results are often obtained, owing to decarburisation. For Rockwell C, and to some extent also for the other Rockwell methods, where the indentation load is fixed and fairly high, the thickness of the material must also be considered. The effect of specimen thickness has been studied for the Rockwell C method. If due consideration is given to the variation with thickness, this method can in some cases be used with sufficiently high accuracy down to a strip thickness of about 0·5 mm.

The other Rockwell methods for hardened steel, such as Rockwell N_{45}, N_{30}, and N_{15}, which are intended for the testing of fairly thin strip steel, do not, in general, meet the requirements of an accurate testing method.

Determination of hardness through ultimate tensile strength has been shown to give satisfactory agreement with results from Vickers testing on a cross-section, and can therefore be used with approximately the same accuracy as Vickers.

Some views on the problem of converting hardness figures to other scales, and the errors incurred therein, are stated.

METALS CORROSION

Corrosion or Protection at Gaps in Metallic Coatings on Steel.

By U. R. EVANS. (From a paper presented at the *Fourth International Conference on Electrodeposition and Metal Finishing, London*, April 21, 1954, 14 pages, 4 illustrations.)

THE state of affairs at a gap varies according to whether the coating metal is cathodic or anodic to steel, but a given metal may be cathodic in some circumstances and anodic in others. A departure from the normal polarity may occur if the liquid contains complex-forming substances ; thus, tin, which is generally cathodic to steel, becomes anodic in the presence of fruit acids and, as a result, tin canisters can be used for canning fruits. Coatings of anyhydrous oxides (which transmit electrons) shift the potential in the cathodic direction, whilst coatings of hydrated oxides (which transmit ions) shift it in the anodic direction. Impurities in alumina facilitate the transmission of electrons, and pure aluminium covered with an almost non-conducting oxide film, is anodic to aluminium-copper alloys, which form a better conducting oxide film. This explains the success of cladding such alloys with pure aluminium.

A gap in a cathodic coating may occasionally cause corrosion more intense than that which would occur on uncoated steel, but such intensification is rare. Several cases in which definitely porous coatings of cathodic metals provide effective protection are known, these including porous coatings of lead for protecting steel against industrial atmospheres, and the highly discontinuous tin coats which can be applied to steel before painting. Explanations of these and other cases, based on well established electrochemical principles, can be suggested.

A gap in an anodic coating does not necessarily lead to corrosion of the exposed steel, which often receives cathodic protection. In the opening stages, the metal may be " sacrificed " to provide this protection, but in many circumstances the cathodic reaction then deposits a layer (calcium carbonate, zinc hydroxide, or aluminium hydroxide in different cases—sometimes converted later to clinging, protective rust), and prevents attack on the steel in a way which involves no attack on the coating metal.

THERMODYNAMICS

The Calculation of Mass-Transfer Rates in Absorption, Vaporisation, Condensation, and Combustion Process.

By D. B. SPALDING. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, April 1954, 24 pages, 22 illustrations.)

MASS-TRANSFER rate is commonly taken to be equal to the product of a mass-transfer coefficient and a concentration difference. This is moderately satisfactory when the concentration differences are small but may lead to serious error when the differences are great. There is no recognised procedure for use when chemical reaction is present. The sources of doubt are chiefly the nature of the driving force for mass transfer and the relation between this driving force and the mass-transfer rate.

Particularly when chemical reaction occurs, analysis of the mass-transfer process may become extremely complex. Solution of all the relevant equations would be a formidable mathematical task. Moreover, it would, in general, be superfluous, because the physical properties of the fluids in question are seldom known with an accuracy commensurate with an exact solution, and large safety factors have to be allowed, to account for changes in the operating conditions of the equipment. Precise and inevitably complicated expressions for the mass-transfer rate in particular circumstances are usually less valuable to the designer than a single, simple, and universal method of calculation which will give the mass-transfer rate in any system with fair accuracy, and which will show clearly the relative magnitudes and directions of the effects the design variables will have on performance.

This paper presents a general method of calculation for mass transfer across a phase boundary. The emphasis is on systems in which the flow is external to the body engaged in mass transfer, but flow within a duct or a bed of packed solids is also treated, with the restriction that the conditions at the interphase boundary are uniform. The case of counter-flow of the two phases is not discussed. Mass transfer in gases is chiefly con-

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sidered, but the treatment applies also to liquids.

Mass-transfer processes are shown to be capable of description in terms (a) of an equation, which is the same for all types of mass transfer, relating the mass transfer rate to the Reynolds number and other conditions; and (b) of a driving force, called the transfer number, which appears in the common equation, but which has a different form for each type of mass transfer. Transfer numbers for absorption, vaporisation, condensation, and the combustion of carbon, metals, and liquid fuels are derived. The mass-transfer rates predicted in combustion are compared with experimental data.

WELDING

A New Type of Primer for Resistance Welding.

By A. J. ELLEMAN and N. D. P. SMITH. (From a paper presented at the *Fourth International Conference on Electrodeposition and Metal Finishing, London*, April 23, 1954, 12 pages, 3 illustrations.)

THE increasing use of electrical resistance spot welding in fabricating structures from mild-steel pressings has presented a number of difficult problems in protecting the inner surfaces of the welds from corrosion.

If the parts are painted with conventional materials before assembly, then the high electrical resistance of the paint makes welding impossible, unless paint is removed in the region of the weld. If, however, the inner surfaces near the weld are not painted before assembly, it is difficult, if not impossible, to ensure that paint reaches these surfaces in subsequent operations. At present, this problem is partially solved by using one or more of the following methods :—(1) Coating the region of the welds with an electrically conducting primer before assembly; (2) welding through wet or soft coats of conventional primers; (3) removing paint in the region of the weld from previously coated parts; and (4) dipping the assembled structure. Of these alternatives, the use of electrically conducting primers appeared to the authors to be one of the most promising.

This paper describes an exploratory survey of alternatives to conventional electrically conducting welding primers, which suffer from the disadvantage that the very high proportion of conducting filler, needed to give adequate conductivity for welding, places severe limitations on the composition of the primer.

It is shown that nickel powder is a very much more effective conducting filler than non-magnetic metal powders, such as zinc. The nickel particles, by virtue of their mutual magnetic attractions, form chains of low electrical resistance, whereas, for non-magnetic powders, the inter-particle attractions and the probability of inter-particle contacts are much less.

It is possible to make coating compositions, containing only moderate proportions of nickel powder, with adequate conductivity for welding. These compositions have been covered by patent. The nickel powder does not appear to affect the protective qualities of the coating adversely. The main disadvantages in the use of nickel as a conducting filler are its high price and its tendency, in common with most other metallic fillers, to a high rate of settlement.

POSTGRADUATE EDUCATION IN ENGINEERING

(*Concluded from page* 183)

being attached to the respective graduate department. In Sheffield, the Department of Mining has a postgraduate school with two years' attendance, whereas the Postgraduate Schools of Physical Metallurgy and of Applied Mechanics are also offering short courses of five weeks duration, and teach research methods of direct benefit to the firms sponsoring students. The School of Applied Mechanics is fully independent and has its own professor. Cambridge provides one year's full-time postgraduate instruction on structures and welding, making use of the University's extensive structural research facilities and of the British Welding Association's research station.

With regard to Birmingham, we are able to speak at first hand, inasmuch as we were recently given the opportunity of visiting their Graduate School of Thermodynamics and Related Studies. This School has now been in operation for over two years, and its curriculum provides instruction at a high level in thermodynamics and other subjects related to heat engines, including gas turbines. Five subsidiary courses comprise lectures on Dynamics of Machines, with special reference to the treatment and analysis of vibrations of all types; Strength of Materials, including elasticity, creep, fatigue, and behaviour at high temperatures; Instrumentation; Mathematics; and Oil-Engine Practice, the latter course being given by a well known engineer engaged in the oil-engine industry. The normal entrance qualifications are an Honours Degree in Mechanical Engineering, together with a minimum of two, though preferably three or four, years of practical experience in industry. On completion of the twelve-month course, successful candidates qualify for the award of M.Sc. In special circumstances, applications for entrance may be considered from non-graduate engineers with suitable alternative qualifications. In such a case, the course would take two years and the award would be the Diploma of Graduate Studies.

The outlook is unsettled and depends chiefly on the attitude of private industry. In all fairness, it must be said that industry is facing greater difficulties than the Universities, mainly in questions of personnel management and employment practices. The more highly trained men are freer to change their jobs when dissatisfied. Older men may resent the higher status of fresh entrants from post-graduate education. Men returning from advanced courses may become impatient at practical difficulties in introducing new methods and may leave, so that no return is obtained for the money spent on their support while at the University. These difficulties, however, are those of transition. Once more highly trained men are accepted, the disadvantages will largely disappear, and if a firm loses a sponsored man, it may also gain other men who have been sponsored by other firms.

So far, the technical Government departments have been keenest to profit from the postgraduate opportunities offered by the Universities. Firms in the Commonwealth and foreign countries, too, seem to be aware of the opportunities offered. The Nationalised Industries appear to be more reluctant and, except for a few large firms, private industry still lags behind. On the whole, however, response has been good, though admittedly it could be much better.

Insofar as the Universities are concerned, the new departments are busy with work in expanding and establishing themselves fully, and are prepared for an increased interest by industry and a larger attendance by students. Nevertheless, behind this initial spurt there lies the question whether expansion will go on, as it must, if the full programme is to be implemented, or whether the Universities will be forced to bide their time. The one further contribution of the Universities may be a greater uniformity in granting a signal award, preferably the M.Sc. or an equivalent, for the successful completion of a postgraduate course of one or two years, without the need for original research; the greatest advantage will be gained from these courses if, at least during this period, the student devotes all his attention to the advanced instruction. The difficulties of the Universities in consenting to such an action should not be underrated, because the standing of a University degree must not be lowered. Nevertheless, such an award may be an additional inducement to students and may well help those firms which intend to employ in suitable positions technical men with scientific postgraduate training.

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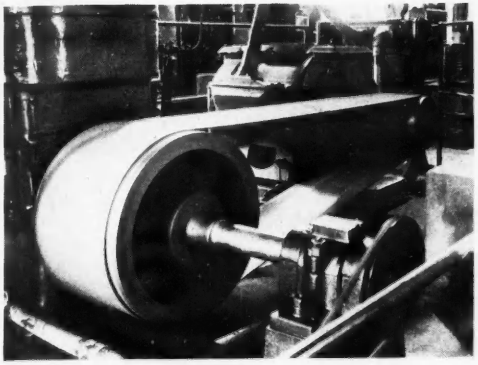
BRITISH INDUSTRIES FAIR, 1954

In our April issue, we previewed some of the exhibits at the 33rd British Industries Fair, which took place this year between May 3 and May 14. In the following pages, a further selection of exhibits is reviewed.

Several working machines using " Miraclo " flat belts were exhibited by **Stephens Belting Co. Ltd.,** of Snow Hill, Birmingham, in conjunction with their Associates, **Ira Stephens Ltd.,** of Ashton-under-Lyne.

These belts, which are made of plastic and chrome leather, have several notable features, among which may be mentioned the following :—They are unharmed by oil or grease; they are suitable for speeds up to 10,000 fpm, and for ratios above 20 to 1, without starting slip; they have virtually no stretch; their elasticity absorbs shock loads, thereby eliminating loss of speed and power; drives of even up to 80-ft centres are practicable; and they can be supplied for all powers from 1 to 1000 hp.



The illustration shows a 125-hp " Miraclo " belt drive to a Holman air compressor.

A complete range of engineers' small tools treated by the Macrome process, was exhibited by **Macrome Limited,** of Aldersley, Wolverhampton.

The range included drills, reamers, milling cutters, turning tools, taps, dies, bandsaws, hacksaws, etc. In addition, a wide range of hand tools was displayed, including spanners, screwdrivers, hacksaw frames, and saws.

In addition to a wide range of transfers for the engineering, electrical, transport, food, packaging, drink, and soap industries, and for institutional and domestic decorative purposes, **Kaylee Transfers Ltd.,** of Long Eaton, Nottingham, displayed examples of the application of transfers for the permanent marking of rubber products, in which the transfers are applied to rubber before curing, so that no separate process is required.

Recently, A.I.D. approval for aircraft transfers was secured, so that, with the perfection of specially strong adhesives, Kaylee transfers for aircraft, fully resistant to all conditions of supersonic speeds, variable climates, and hard usages, are available.

Two new machines in the range of exhibits of **The Midland Saw & Tool Co. Ltd.,** of Birmingham, were the Major/ATC and the 16-in. toolroom bandsaw machines. The Major/ATC is a toolroom bandsaw machine, with butt welder for saws up to $\frac{5}{8}$ in. incorporated, and a speed range of up to 1600 fpm. The 16-in. machine has a speed range of from 60 to 500 fpm, and is powered by a 1-hp motor. It can also be supplied with speeds suitable for the cutting of non-ferrous metals, sheet metals, and wood.

Other items exhibited included a 9-in. universal woodworker, an electric butt-welding unit for saws up to 1-in. in width, an overhead cut-off machine for aluminium extruded sections or wood, and a 36-in., 8-speed bandsawing machine with an automatic moving table of 50 in. × 24 in., and a range of blade speeds and table-feed speeds suitable for the cutting of ferrous metals and the harder non-ferrous metals, such as manganese bronze, phosphor bronze, etc.

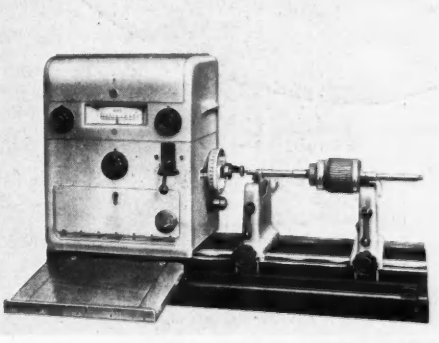
In addition to a comprehensive range of plating barrels, rotary finishing barrels, lacquering machines, polishing machines, filter units, etc., **W. Canning & Co. Ltd.,** of Birmingham, exhibited the latest type of hydraulic-electric automatic plating plant.

This plant, which was approximately 35 ft in length and was in operation for the benefit of visitors, is of the single-process type, complete with ancillary equipment, including rectifiers, transformer, voltage regulator, filter, and rotary air pump. Lifting and transfer of the plating racks from one tank to another are carried out by a hydraulic system, the whole conveyor being operated as a single unit. Heating can be arranged for either steam or electricity, as required. Exhaust ducting is supplied, where necessary, and this can be arranged for either overhead or underground discharge. Control of the entire plant is maintained from a cabinet mounted near the loading and unloading stations.

Automatic plant of this type can be supplied for all plating processes. Larger units, incorporating multiple processes, such as copper, nickel, and chrome plating in a combined installation, can be supplied to order.

Among the exhibits of **W. & T. Avery Limited,** of Birmingham, were the Model 7206 electrodynamic balancing machine (illustrated), the Model 6406 visual hardness-testing machine, and the new " Shadoweight " precision scale, intended for industrial repetition weighing and check-weighing.

Weight indication on this type of scale has previously been by a pointer and chart. Indication on the new scale is by means of a band of light projected onto a ground-glass screen. This method gives greater accuracy and reduces eye-strain—an important factor when the same pre-determined quantities are repeatedly weighed and checked. The scale has a capacity of either 2 oz., 4 oz, or 1 lb, and is so sensitive that the weights used with it have to be specially adjusted.



Another new exhibit was the Model 6105CCG tensile-testing machine, which is compactly constructed in a single unit. It is extremely versatile, and can be used for testing a very wide range of materials, ranging from metallic wire or strip to plastics, textiles, and cement.

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The D.S.P. 'B' Series Mountings are designed to isolate a wide range of vibration frequencies in medium-weight machinery.

The 6 sizes in the range and the large number of rubber compounds available for each mounting permit loads from 60 to 1,000 lbs. to be carried and frequencies down to 500 c.p.m. to be isolated. Alternative assemblies of the mounting enable a wide variety of applications to be catered for.

A complete range of D.S.P. Anti-vibration Mountings is available for the insulation of instruments and all types of machinery; D.S.P. technicians will gladly advise on any vibration problem.

SPECIALISTS IN PRECISION RUBBER ENGINEERING

Dunlop Special Products Limited (Engineering Components Division), Fort Dunlop, Erdington, Birmingham
Telephone: Erdington 2121 Extension 341 & 767.

3SPC/PC6C

There are good hack saw blades....

....better hack saw blades....

but the best are

Eclipse

Made by James Neill & Co (Sheffield) Ltd. and obtainable from your usual supplier

EH237

A comprehensive display of Tufnol, in the form of sheet, tube, and rod, was exhibited by **Tufnol Ltd.**, of Perry Barr, Birmingham, together with examples of engineering components produced from these basic shapes with the usual machine tools or moulded to shape during manufacture.

Of special interest were the water-lubricated bearings and slipper pads for rolling mills, and quiet-running gear wheels, ranging from small gears for instrument movements to pinions transmitting heavy loads, some of which are illustrated. Other items of interest included terminal boards, insulators for voltages up to 660 V, the Tufnol drilling jig, weighing only 10 lb, the Tufnol tray for drying lenses after immersion in mildly acid solutions, and selections of intricate punchings, including " packets " for rotary switches, gaskets for carburettors, filters for water softeners, etc.

In addition to a wide range of products exhibited by **Permali Limited,** of Gloucester, including Permali silent gears, bearings, and other mechanically stressed parts, selections were displayed of Permali insulators and " Dialam " bushings and terminals.

Featured were two new grades of Permali, now available in commercial quantities. Grade TH Permali has been specially developed for use in the tropics or elsewhere under operating conditions of high humidity. It possesses the same properties of high mechanical and dielectric strength as standard grade EH Permali, but has substantially improved resistance to moisture. Grade BH Permali is a non-electrical grade with pronounced resistance to most chemicals in industrial concentrations, particularly in the form of fluids, vapours, and gases. It is therefore recommended for the fabrication of chemically resistant structures and components, of which several examples were shown, including a water-treatment unit, in which water is demineralised by the ion-exchange process ; a field rate-meter unit, which is a portable prospecting unit for locating uranium or for geographical mapping and the examination of mine workings ; and a fume-extraction hood and fan casting.

A range of mobile compressor sets, with displacements from 9 to 50 cfm, all based on their perfected " Hydrovane " rotary design, was exhibited by **The Hymatic Engineering Co. Ltd.,** of Redditch, Worcs. Powered either by petrol engine or electric motor, each has a volumetric efficiency of over 90% at pressures up to 100 psi.

The smallest set exhibited was the portable 303, marketed as a complete spray-painting outfit, complete with spray gun and a 30-ft hose. This outfit delivers 3·25 cfm at 35 psi with a $\frac{1}{3}$-hp motor, and is claimed to provide a higher rate of coverage with any material than any other machine of less than 3 hp.

The largest " Hydrovane " sets, with displacements of 40 and 50 cfm, in common with the intermediate sizes, are all capable of operating simultaneously various combinations of spray guns and smaller appliances.

A comprehensive range of ancillary equipment was also exhibited, including the type PH107 lightweight hammer, which, with its striking rate of approximately 6000 blows per minute at the very low consumption of 3 cfm at 80 psi, can be employed on Rawlplug drilling, channelling, and routing on concrete and brickwork.

In addition, 2- and 5-gallon pressure-feed containers, in association with " Hydrovane " compressors, were used in displacement spraying demonstrations.

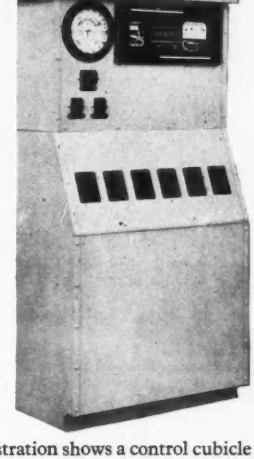
A comprehensive range of solenoids, exhibited by **Westool Ltd.,** of Bishop Auckland, Co. Durham, included solenoids for a.c. performances of 1 lb pull or thrust at 1-in. stroke up to 20 lb at $1\frac{3}{4}$-in. stroke, pull-type only, and for d.c. up to 300 lb at 5-in. stroke, pull or thrust types.

In addition, Warner electric motion-control brakes, clutches, and clutch couplings, which previously were obtainable only from the U.S.A. and which are now manufactured in Great Britain, were shown for the first time. The exhibit showed the Warner brake and clutch under simulated working conditions, for both manual and automatic control.

Another exhibit was the " Westair " Climatiser, which is a packaged air conditioner, also previously made only in the U.S.A., and now manufactured in Great Britain and shown for the first time.

Exhibits of **The Belmos Company Ltd.,** of Bellshill, Lanarkshire, included metal-clad switchboards and group motor controls in single-, double-, and triple-tier formation, and contactors from 30-A to 450-A rating, with a variety of instrumentation and control arrangements showing how individual requirements can be incorporated in standard equipment. In addition, samples of control pillars for single- or multi-motor control were displayed, included direct-on rotor resistance and auto-transformer starters, while a new design of housing for multi-motor control was shown for the first time.

Flameproof exhibits included a two-unit switchboard, showing coupled together a circuit-breaker distribution unit of 200-A rating, and a direct-on starting unit of 75-A capacity. Of special interest to the oil industry was a 30-A contactor unit with isolator, which can be used as a single unit or mounted in double-tier formation. A new 100-watt flameproof lighting fitting, certified for Groups I, II, and III gases, was also exhibited.



The illustration shows a control cubicle for a six-stage automatic power-factor correction installation. By automatically controlling the capacitor switching contactors, this unit ensures that the desired power factor is maintained.

Wimet

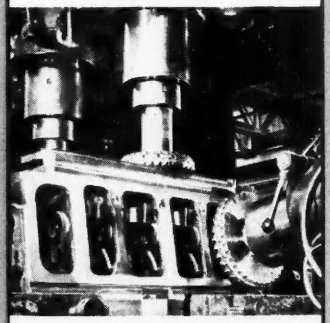
Tungsten Carbide Tipped

MILLING CUTTERS

Backed by over 26 years carbide tooling "know-how"

This is the TYPE 'A' cutter, one of the first carbide cutters ever made. Specially designed for milling cast iron and non-ferrous metals, it is extremely efficient for milling slender castings and components when low tooth loading is required to offset the effects of vibration.

Here's an example of multiple face milling with type 'A' cutters.



At Ruston & Hornsby Ltd., Lincoln, Wimet type 'A' cutters are machining diesel engine cylinder blocks on four faces simultaneously, with 20 h.p. applied to each spindle.
The angular cover faces are completely machined at one pass with 16″ cutters, and the joint faces roughed and finished with 12″ left-hand and right-hand cutters.
The cutting speed in all cases is 240 ft. a minute, with ¼″ depth of cut when roughing and about 0·020″ for finishing. Three blocks are machined every 35 minutes.

These are other cutters in the range.

MULTIMILL

Made in two basic styles, one for steel, the other for cast iron. Solid stress-free carbide inserts.

ALUMILL

For milling aluminium and light alloys at the highest speeds obtainable on modern machines.

HEVIMILL

A heavy duty cutter for steels, particularly designed for the heavy engineering industries.

HI-TEN

For heavy metal removal on alloy steels of medium and high tensile strengths.

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in the selection, application, and reservicing of carbide milling cutters. Send for your copy now.

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Wickman

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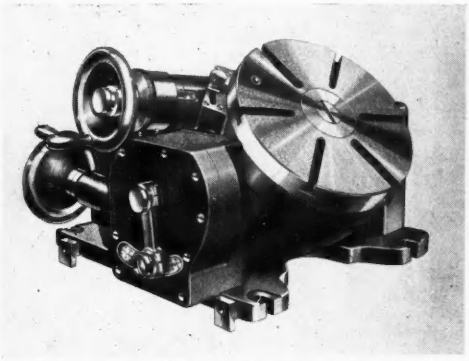
GAUGE & TOOL EXHIBITION, 1954

As announced by the Gauge and Toolmakers' Association, the fourth Gauge and Tool Exhibition will be held at the New Horticultural Hall, Westminster, London, S.W.1, from May 17 to May 28, 1954. Some of the exhibits are previewed in the following pages.

In addition to their well-known range of " Matrix " gauges and measuring instruments, **Coventry Gauge & Tool Co. Ltd.,** of Fletchamstead, Coventry, will be exhibiting several new instruments, among which is an 8-in. high-precision tilting and rotary table (illustrated), specially designed for use on small jig-boring machines for light milling operations. Angle inclination of the table is read by means of a built-in vernier to one minute of arc. The overall height of the table in the horizontal position is 7 in., and in the vertical position 10½ in.

Also to be exhibited for the first time will be a 12-in. rotary table, for use on small jig borers and milling machines. This equipment is extremely compact in design, its overall height being only 3¼ in. By means of a vernier, direct readings to 5 seconds of arc can easily and quickly be taken.



Other new equipment will include tri-roll caliper gauges for checking mass-produced threaded components, a highly accurate optical tool-angle gauge for the precise measurement of many types of lathe tools, an optical twist-drill gauge, and a set of calibrated steel balls with a calibrated accuracy of 0·000025 in.

A wide range of moulds, tools, and dies for the plastics industry will be exhibited by **B.I.P. Tools Ltd.,** of Erdington, Birmingham. Moulds will be displayed according to various manufacturing techniques, and examples of cold hobbing will be included among a display of component parts, exemplifying some of the many mould-making operations.

In addition, heating platens, coils, etc. will be exhibited, to illustrate the induction heating system perfected for the efficient heating of moulds.

A selection of standard tools, so designed as to require the minimum of adjustment in the manufacturer's tool-room, will be exhibited by the **Plessey Co. Ltd.,** of Ilford.

Among these tools will be the latest Plessey pillar-type bolster set, which combines the advantages of pillar-type press tools with the economy of the interchangeable standard die set. Each die set consists of a backing plate, punch plate, stripper, and die, and is supplied with all plates pre-machined and accurately ground and pre-assembled.

Standard drilling jigs, taps, screw and tap gauges, and a range of plain ring gauges, as well as plug and special plate gauges, will also be exhibited. The standard drill jigs include leaf drill jigs, sandwich drill jigs for general usage, and box drill jigs for three-face drilling.

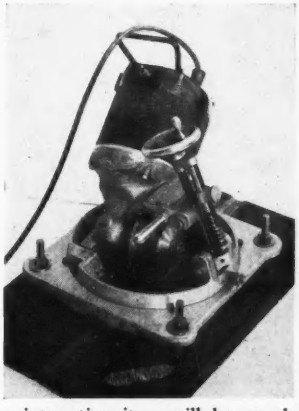
In addition, a selection of plain hardened steel ring gauges, ground and lapped from $\frac{3}{16}$ to 2 in., will be shown, as also will be the Plessey crimping tool, which enables unskilled labour to make a reliable solderless wiring connection quickly and easily.

A comprehensive range of ground and unground form milling cutters, thread mills, circular form tools, and all types of standard cutting tools will be exhibited by **Reliance Precision Tools Limited,** of Staines, together with a selection of more specialised gear-cutting tools and hobs, gear-shaper cutters, and bevel-gear cutters, and the special components these produce.

In addition, jigs, special attachments, sharpening attachments, precision divide plates, and wheel crushers will be displayed.

The " Weld-Prober," to be exhibited by the **Kemworthy Jig and Press Tool Co.,** of London, S.W.19, is a portable electric machine for cutting out specimens of welded joints for testing purposes. The specimen produced is boat-shaped, and is large enough to machine into testpieces for torsion and bend-test machines.

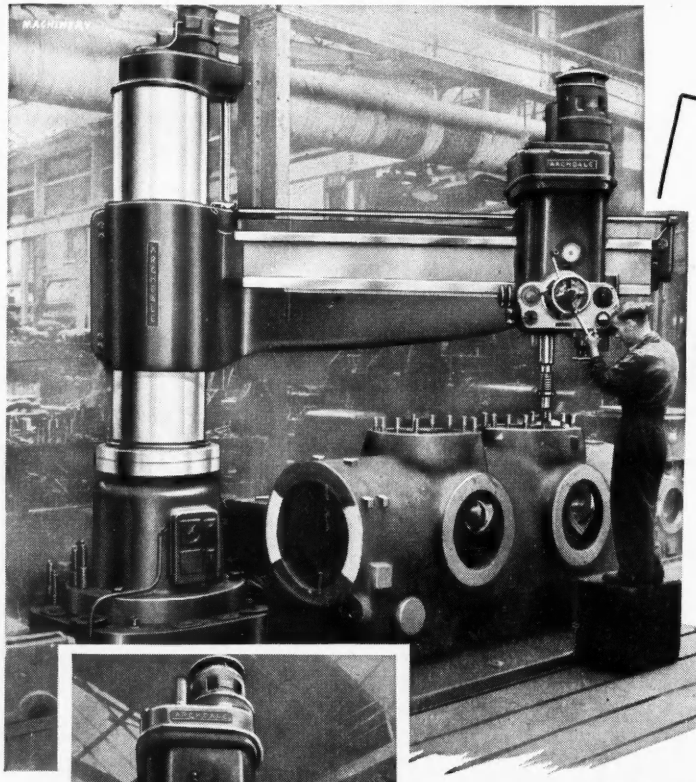
The machine can be adjusted to cut specimens from plate of from ⅛ to 1¼ in. in thickness, and, apart from the ease with which the specimen can be cut out, the resulting hole is of an easy shape for re-welding afterwards. The machine uses a special saw, which is shaped like a saucer, with teeth around the edge. The illustration shows the " Weld-Prober " set up for cutting a specimen longitudinally from a welded joint. A specimen can be seen in the foreground.



Another interesting item will be an electronically controlled tube expansion unit, suitable for expanding tubes in the end plates of heat exchangers, condensers, oil-refinery fittings, etc.

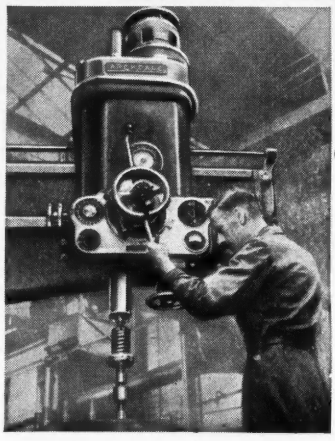
In addition to a selection of jigs and fixtures, **Holt & Mosedale Ltd.,** of Smethwick, Staffs., will be exhibiting spray lubrication equipment for dies on forging presses. The purpose of this equipment is to replace the method, at present largely used, of lubricating these dies by hand with a mop dipped in a suitable lubricating medium.

The functioning of this apparatus is entirely automatic ; the pressing of a button by the operator causes the spray jets, which are mounted on a block fixed to arms operating on the lazy-tongs principle, to move forward between the two sets of dies, to be held there for a predetermined period, while spraying takes place both



DRILLING TAPPING AND STUDDING

CRANKCASES FOR HEAVY MARINE REFRIGERATION EQUIPMENT AT J & E HALL LTD. DARTFORD.



ARCHDALE

HYDRAULIC

for maximum performance

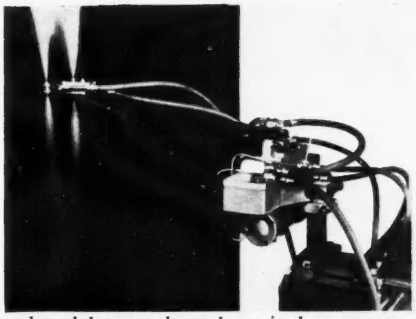
- *PRESELECTION OF SPEEDS AND FEEDS*
- *HYDRAULIC CONTROL*
- *AUTOMATIC LOCKING*

This versatile and powerful machine, with **hydraulic control** and **pre-selection of speeds and feeds**, has shown outstanding results on heavy duty drilling, tapping and studding at J. & E. Hall Ltd., Dartford.

Capacity from solid, in cast iron 4 in., and in steel 3½ in. dia. There are 22 speeds, 11 to 1450 r.p.m. and 18 feeds, 8 to 540 r.p.i. Sizes range from 5 ft. to 12 ft. spindle radius.

JAMES ARCHDALE & CO. LTD. BIRMINGHAM
ENGLAND

Sole selling agents
ALFRED HERBERT LTD. COVENTRY & BRANCHES



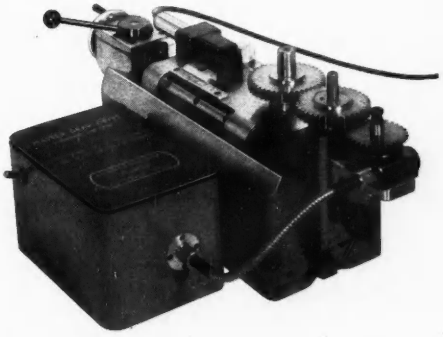
upwards and downwards, as shown in the accompanying illustration, and then to be returned to the normal out-of-die position, without any further intervention from the operator. The whole cycle can be varied to suit particular dies or operations.

Equipment to be exhibited by **George H. Alexander Machinery Ltd.,** of Birmingham, will include the following :—A complete range of " AB " honing equipment, including a new range designed for the American market ; the " Galex " adjustable plug gauge for detecting taper, bell-mouth, and other inaccuracies ; the " Alexander " sheet-metal testing machine, including a new range of auxiliary tools for deep-drawing tests ; the " Rockwell " hardness tester, incorporating the latest designs for simple and convenient operation ; an assortment of special-purpose gauges, made to customers' requirements ; an improved type of sine bar ; a range of attachments for use on toolmaking machines ; and demonstration models of the latest range of P.G. optical instruments, including comparometer, angle meter, profiloscope, projectoscope, and cam-measuring machine.

In addition to a new range of measuring equipment, including sine tables of both single- and double-leaf types, a universal surface plate comparator, and an indicating beam caliper for the measurement of large diameters, **J. Goulder & Sons Limited,** of Kirkheaton, Huddersfield, will be exhibiting two parallel ranges of rolling gear testers.

The first of these is a universal range of high accuracy and great versatility, intended for inspection departments and precision gear-cutting shops. The second, known as the " S "-type range, is intended for general users alongside the gear-cutting machines, or for the smaller shop where elaborate apparatus is not required. There are three sizes in each range, as follows :—

No. 1 Tester :—Capacity, 4-in. centres ; intended for instrument gears of high accuracy.



No. 2 Tester :—Capacity, 9-in. centres ; intended for automobile and aircraft factories.

No. 4 Tester :—A large, power-operated machine, for very large gears up to 32 in. centres and 400 lb in weight.

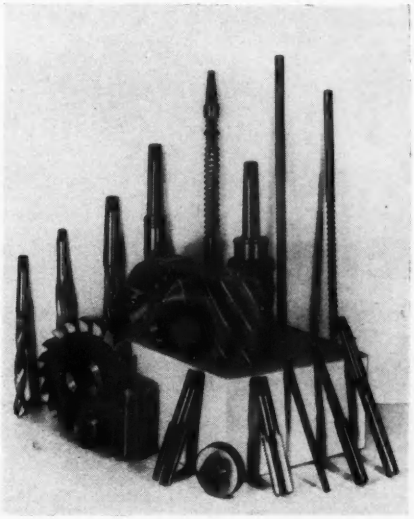
4-in. " S " Type :—Capacity, 4-in. centres ; suitable for power-tool manufacturers.

9-in. " S " Type :—Capacity, 9-in. centres ; intended for general workshop use.

16-in. " S " Type :—Capacity, 16-in. centres.

The illustration shows the No. 1 Tester, with motorised drive.

A comprehensive selection from their wide range of engineers' small tools and workshop accessories will be exhibited by **B.S.A. Tools Limited,** of Birmingham, including twist drills, milling cutters, sleeves and sockets, milling-machine arbors, reamers, metal-slitting saws, taps, dies, dieheads, broaches, cam-action machine vices, oil and suds pumps, and thread rolls.



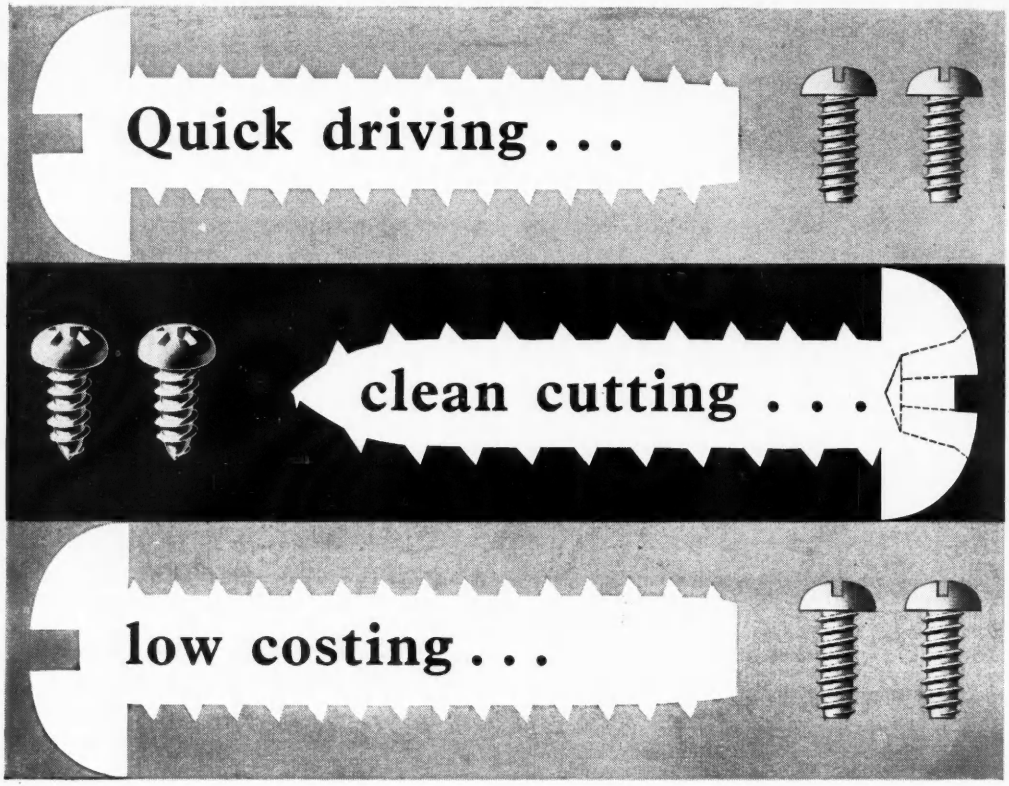
B.S.A. cast milling cutters will also be available for inspection. These have been introduced in the interests of economy and efficiency, and it is claimed that B.S.A. Tools' new casting method gives the cutters a performance at least equal to that of conventional cutters, and permits them to be offered at 25% less than the cost of H.S.S. cutters.

The illustration shows a representative selection of B.S.A. small tools.

A complete range of precision dial measuring equipment, including dial indicators, comparators, cylinder gauges, small bore gauges, dial test indicators, dial micrometers, etc. will be exhibited by **Thomas Mercer Limited,** of St. Albans, Herts., who will be introducing for the first time their new Model 180 series indicators.

A new feature of the Model 180 instrument is a completely re-designed gear train. Whilst maintaining a 1 $\frac{11}{16}$-in. diameter across the bezel, scale graduations and readings now include 0-5-0 in 0·0001 in., 0-10 in 0·0001 in., 0-15-0 in 0·0005 in., and 0-30 in 0·0005 in., these being in addition to the graduations and readings normally supplied with the Model 80. All Model 180 series indicators are fitted with a secondary hand, i.e., a revolution counter.

In addition to the Model 180 series, the " Alpha " range of dial indicators has been increased, and in the 2$\frac{1}{4}$-in., 3-in., and 4-in. diameter range it is now possible

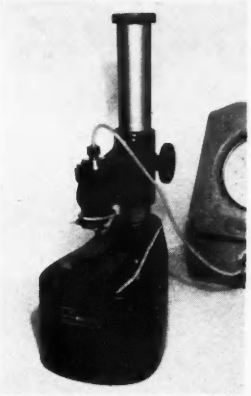


Taps cost money. Tapping takes time. Nettlefolds Parker-Kalon self-tapping screws eliminate both. They cut their own thread and hold securely without the aid of auxiliary fastening devices. There's no risk of broken or stripped screws holding up the assembly line. They can be driven by hand power.

There are five different types of thread for different materials. The most generally useful being types A & Z which between them cover a wide range of materials from stainless steel to plastics. They are available with all types of heads either slotted, Hexagon, or with Phillips Recess.

GET IN TOUCH WITH **GKN**

GUEST KEEN & NETTLEFOLDS (MIDLANDS) LTD. · SCREW DIVISION, BOX 24, HEATH ST., BIRMINGHAM, 18
S/P.NPK/2907



to include open-scale graduations, i.e., 0-15-0, 0-30, 0-10, and 0-20, all in 0·0005 in.

The Mercer air gauge will also be shown, together with Mercer gap gauges of entirely new design, Mercer microjet plunger units, and the Mercer air comparator, incorporating a microjet plunger unit measuring head (illustrated).

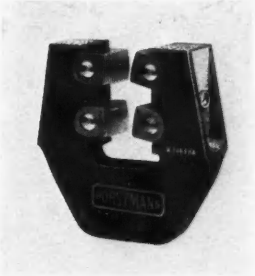
Exhibits of **Hall & Pickles Ltd.,** of Manchester, will comprise a wide range of special tools and some large gangs of cutters. In addition, there will also be a representative display of "Hydraloy" hard-metal and "Hydraweld" butt-welded standard tools, and "Hydra" high-speed steel tool bits, together with a range of "Hydraloy" rotary and percussive drill bits.

A number of new models of "Baty" dial gauges and measuring instruments will be exhibited by **J. E. Baty & Co. Ltd.,** of London, S.W.1, including a dial indicator (illustrated) with a 2½-in. range, believed to be the longest travel in a high-magnification indicator as yet made in Great Britain. The accuracy of the indicator is particularly good, despite its long range, and it supplements a series of long-travel gauges which are very popular here and abroad.

The 2½-, 3-, and 4 $\frac{7}{16}$-in. diameter range of "Baty" dial indicators has been increased to 96 models, with the addition of new open-scale types. Graduations of 0-30, 0-15, 0-20, and 0-10-0, reading in either 0·001 in. or 0·0005 in., are now available.

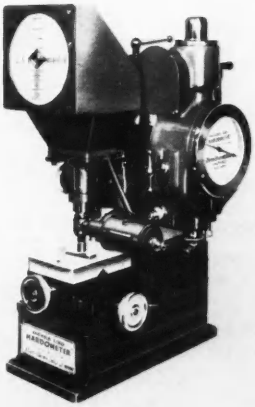
A very wide range of instrumentation incorporating dial gauges will also be exhibited, including dial-indicator sets, magnetic bases, small bore and cylinder gauges, internal recess gauges, dial micrometers, comparators, sinometers for angle inspection, and "Lindley" extensometers. The range of "Westminster" optical projectors will include a completely new bench projector of the reflex type, with both episcopic and diascopic systems.

In addition to their press guard and a representative range of instrument gear hobs (machine-relieved type), **The Horstmann Gear Co. Ltd.,** of Bath, will be exhibiting a full range of screw and plain plug and ring gauges, as well as their new, patented caliper gauge (illustrated).



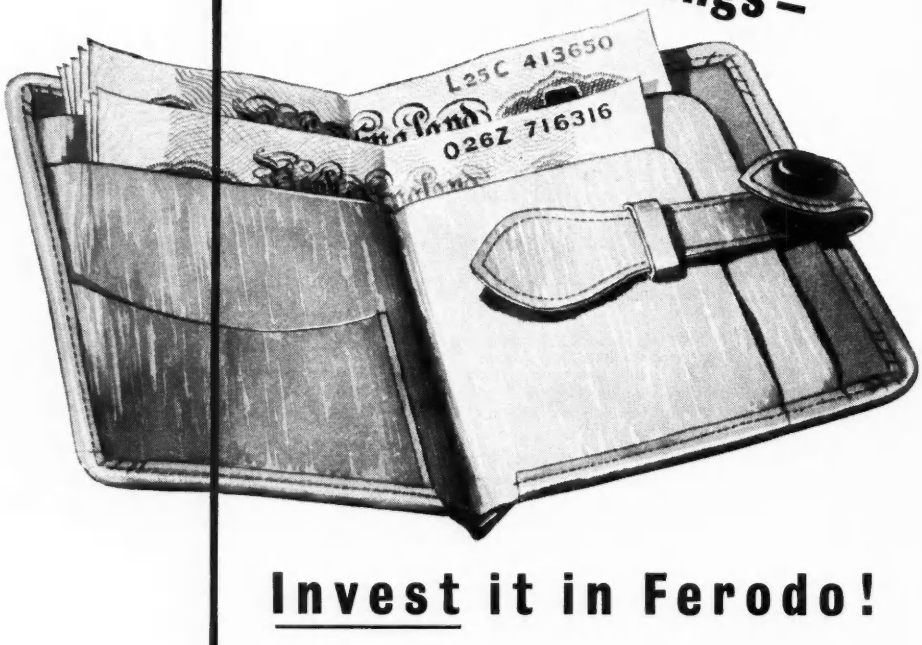
The general design of this new gauge is similar to that of the old model but, as a result of streamlining of the frame and other new features, it is now possible to deal much more simply and rapidly with shouldered work. At present, the new caliper is subject to certain range limitations; most sizes up to 1 in. are available, but other sizes will become available shortly.

In addition to a representative selection of centre drills, reamers, milling cutters, end mills, slitting saws, carbide lathe tools, metal-cutting saws, engineers' files and rasps, and milled-tooth files, **Firth Brown Tools Ltd.,** of Sheffield, will be exhibiting a range of tungsten alloy steel hacksaw blades, circular saws for wood, running ("live") centres, high-speed steel ground thread taps and chaser dies, carbide-tipped circular saws for plastics, etc., and high-speed steel twist drills of all types, from 0·004 to 4 in. in diameter.



In addition, the fixed load "Hardometer" hardness-testing machine and the new "Variable-Load Hardometer" hardness-testing machine (illustrated) will be exhibited and demonstrated.

Don't spend money on any linings –



Invest it in Ferodo!

These world-employed industrial friction linings last longer, act smoother, stay safer than any others. Non-productive maintenance time is slashed, and once Ferodo Friction Linings are fitted, they won't need renewing for a long, long time. So it's easy to see that with more working hours per machine, Ferodo Industrial Brake and Clutch Linings more than repay their installation costs—and quickly too!

FERODO
FRICTION LININGS
for Industry

FERODO LIMITED CHAPEL-EN-LE-FRITH · *A Member of the Turner & Newall Organisation*

NEWS OF THE MONTH

PERSONAL

H.R.H. The Duke of Edinburgh, K.G., P.C., K.T., and **Air Commodore Sir Frank Whittle, K.B.E., C.B., F.R.S.,** have been elected honorary members of the Institution of Engineering Designers, Grand Buildings, Trafalgar Square, London, W.C.2.

Mr. E. F. Alldritt has been appointed publicity manager of Gresham Transformers Ltd.

Air Vice-Marshall C. E. H. Allen, C.B., D.F.C., B.A.(Cantab.), M.I.Mech.E., has joined the Aviation Division of the Dunlop Rubber Co. Ltd., St. George's Road, Coventry, as liaison officer with the Ministry of Supply, the Air Ministry and the aircraft industry. **Mr. S. A. Brazier,** technical manager of Dunlop's General Rubber Goods Division, Manchester, has been appointed technical consultant of the Division. **Mr. A. B. Hadley,** manager of the Dunlop factories in Stoke-on-Trent, has been appointed works director of the Dunlop factory at Benoni, South Africa.

Mr. A. R. E. Arnot, B.Sc.(Eng.), A.M.I.E.E., and **Mr. R. G. Winton, A.M.I.Mech.E., A.M.I.P.E.,** have been elected to the Board of Lansing Bagnall Ltd., Basingstoke, Hampshire. **Mr. H. P. Mott,** chairman of the Institute of Materials Handling, has joined the firm as materials and production controller.

Mr. R. P. S. Bache, managing director of Geo. Salter & Co. Ltd., West Bromwich, is a director of the new company, British Industries Fair Ltd., set up to take over the organisation and management of the B.I.F. from 1955 onwards.

Mr. K. A. Ballard has been appointed by Samuel Osborn & Co. Ltd., Clyde Steel Works, Sheffield 3, special representative for the sale of steel castings. He will be operating for the Company's London office at Donnington House, Norfolk Street, London, W.C.2.

Mr. Robert J. Barclay, managing director of Markham & Co. Ltd., 8 The Sanctuary, London, S.W.1, has been elected a director of John Brown & Co. Ltd.

Mr. C. F. Barnard has been appointed joint managing director of Associated British Oil Engines (Marine) Ltd., with **Mr. J. Jones,** who is also managing director of The National Gas and Oil Engine Co. Ltd. Mr. Barnard has been managing director of Mirrlees, Bickerton and Day Ltd., since October, 1953, a position which he retains.

Mr. J. A. Brooks, B.Sc.(Eng.), A.M.Inst.W., has been appointed superintendent, Motor Department, Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17.

Dr. T. W. F. Brown, director of the Pametrada Research Establishment, and **Dr. A. T. Bowden,** chief research engineer of C. A. Parsons & Co. Ltd., have been awarded jointly the James Clayton Prize for 1953 by the Institution of Mechanical Engineers.

Mr. G. W. Bush has relinquished his position with Renshaw Foundry Ltd., Mill Mead, Staines, Middlesex, whose management will be carried on by **Mr. G. K. Smith** and **Mr. W. T. Morton.**

Mr. H. G. Conway, M.A., F.R.Ae.S., M.I.Mech.E., has been appointed chief engineer of Short Bros. and Harland Ltd., Belfast, in succession to the late **Mr. A. W. S. Clarke.**

Mr. John Creek has been appointed sales director of Fibreglass Limited, St. Helens, Lancashire. Mr. Creek, who joined Fibreglass Ltd. as general sales manager in 1952, is also a director of the recently formed F. A. (Membranes) Ltd.

Mr. J. P. Ford, managing director of Associated British Oil Engines (Export) Ltd., has been elected chairman of the council of the Institute of Export.

Mr. R. J. Foster, D.F.C., A.F.C., has been appointed by The British Oxygen Co. Ltd., Bridgewater House, Cleveland Row, London, S.W.1, as their liaison officer for the Aircraft Industry, the Services and Government departments.

Mr. B. R. Fraser has been appointed manager of the Croyton Refinery of the Vacuum Oil Co. Ltd., in succession to Mr. D. M. Glendinning.

Sir John Hacking, M.I.E.E., has been elected President of the British Electrical Development Association, 2 Savoy Hill, London, W.C.2, in succession to **Sir Henry Self, K.C.B., K.C.M.G., B.Sc., B.A., M.Sc. Sir Harry Railing, M.I.E.E.,** has been elected vice-president, and **Dame Caroline Haslett, Lord Beveridge** and **Captain J. M. Donaldson** have been re-elected vice-presidents for a period of three years. **Mr. S. F. Steward, C.B.E., M.I.Prod.E.,** chairman of the S.W. Electricity Board, has been elected chairman of the council. **Mr. C. R. King, C.B.E.,** chairman of the East Midlands Electricity Board, will be next year's vice-chairman.

Mr. M. M. Hallett, M.Sc., F.I.M., has been appointed director of research to the three Sheepbridge Group of Companies, Sheepbridge Stokes Ltd. and Sheepbridge Equipment Ltd., Chesterfield, and Sheepbridge Steel Castings Ltd., Sutton-in-Ashfield, Nottinghamshire.

Mr. E. D. Hart, A.M.I.E.E., has been appointed deputy director, and **Miss G. E. Moss,** secretary, of the Scientific Instrument Manufacturers Association, 20 Queen Anne Street, London, W.1.

Mr. L. Haworth has resigned from his position of advertising manager of Newton Victor Ltd. and has joined the British Tyre & Rubber Co. Ltd. as advertising manager of the Group.

Mr. I. H. Hedley, M.I.E.E., has been appointed technical adviser and sales representative in Northern England and the Midlands for the Hackbridge and Hewittic Electric Co. Ltd., Walton-on-Thames, Surrey.

Mr. W. H. L. Hewitt, formerly with the General Electric Co. Ltd., Coventry and Stanmore Laboratories, Stanmore, has joined the Board of A. K. Fans Ltd., 20 Upper Park Road, London, N.W.3, as technical director.

Lieut.-Col. P. D. Ionides, D.S.O., has relinquished his directorship with Babcock & Wilcox Ltd., Farringdon Street, London, E.C.4. **Sir Percy Mills, Bt., K.B.E.,** and **Mr. W. F. C. Schaap,** chief engineer of the Company, have been elected to the Board.

Mr. G. A. Jennings has been appointed manager, and **Mr. J. H. Woods,** commercial manager, of the Small Tools Division of B.S.A. Tools Ltd., Sparkbrook, Birmingham. **Mr. H. Williams** has been appointed plant engineer at the headquarters factory at Mackadown Lane, Birmingham.

Mr. T. S. Kilpatrick, director and commercial manager of the Workington Iron and Steel Co. Ltd., has been elected, in addition, a director of the Distington Engineering Co. Ltd.

Mr. F. N. Lloyd, chairman and managing director of F. H. Lloyd & Co. Ltd., James Bridge Steel Works, near Wednesbury, has been elected chairman of the British Steel Founders' Association.

Mr. Ralph Lysell has joined Scientists and Technologists Engineering Partnership Ltd., Abbey House, Victoria Street, London, S.W.1.

Mr. G. R. Marsh, who has been a director of Wickman Limited for fourteen years, has been appointed managing director of the Company.

Mr. H. M. Matthews, C.I.E., M.I.E.E., has been appointed director of engineering to the English Electric Co. Ltd., Marconi House, Strand, London, W.C.2. Mr. Matthews is responsible for

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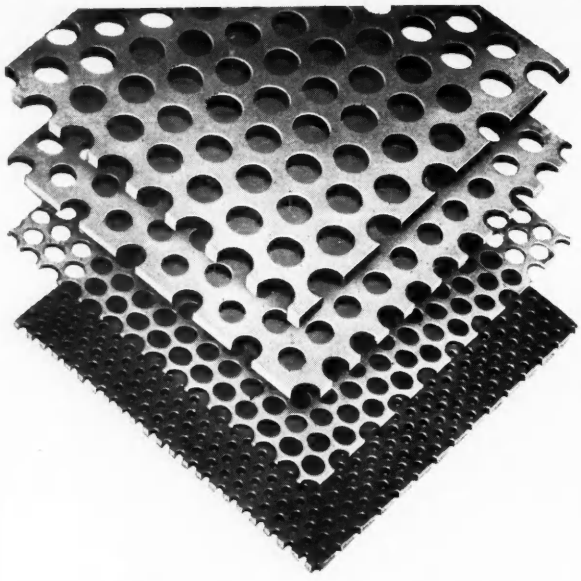

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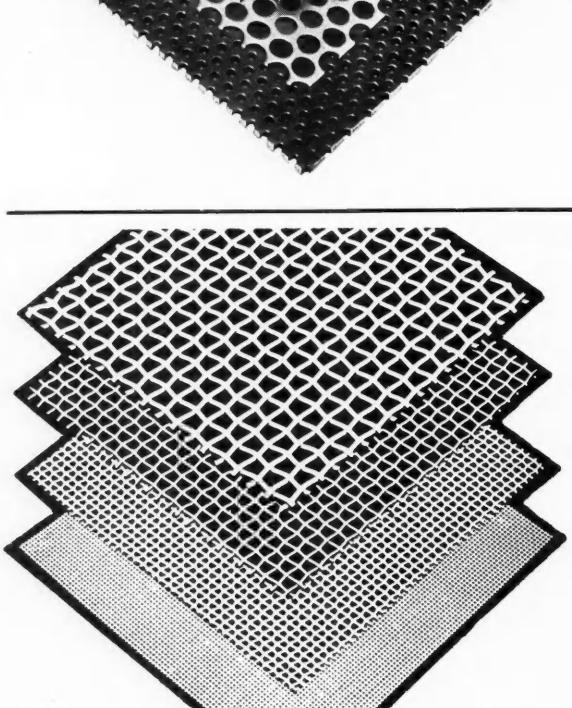

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he co-ordination and direction of the technical policy of the Company.

Mr. S. McCracken, Assoc.M.C.T., M.I.E.E., has been appointed a director of Metropolitan-Vickers, South Africa (Pty.) Ltd.

Mr. Alfred E. Neate, lately Director-General, Machine Tools, Ministry of Supply, has been elected a director of Wickman Limited, Banner Lane, Coventry.

Mr. N. R. Peach, A.M.I.Loco.E., has been appointed district motive-power superintendent, London Midland Region, British Railways, Crewe.

Sir Harry Pilkington has been re-elected President of the Federation of British Industries, 21 Tothill Street, London, S.W.1.

Mr. J. F. Prince and **Mr. A. E. Taylor, A.M.I.E.E.,** have been appointed deputies to **Mr. T. G. Travis,** sales manager of the Witton Engineering Works of The General Electric Co. Ltd., for export sales and home sales, respectively.

Mr. J. P. H. Read, A.M.I.E.E., has been appointed chief engineer (machine section) of the Electric Construction Co. Ltd., Bushbury Works, Wolverhampton, in succession to **Mr. W. J. Stay,** who retired after 47 years of service with the company. **Mr. F. S. Handley** has been appointed assistant chief engineer (machine section).

Mr. Walter E. Schroeder has been appointed chief engineer of The Colonial Iron Works Company, Inc., Cleveland, Ohio, U.S.A.

Mr. N. C. Stamford, M.Sc., M.I.E.E., has been appointed education officer of the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Mr. W. M. Tribute, export advertising manager of Hoover Ltd., has completed 35 years' service with his company. He was one of the first four people to join Hoover Ltd. when it first began operations in London in 1919.

Mr. R. H. S. Turner, M.A., M.I.P.E., has been appointed works manager, and **Mr. A. Paterson, B.Sc., A.R.T.C., A.M.I.P.E.,** assistant works manager, of the Metropolitan-Vickers Electrical Co. Ltd., Trafford Park Works, Manchester 17.

Mr. R. H. Unwin, until recently a director of Ambrose Shardlow & Co. Ltd., of Sheffield, has been appointed export manager of Newall Group Sales Ltd., Old Fletton, Peterborough.

Sir William Wallace, C.B.E., F.R.S.E., M.I.Mech.E., M.I.N.A., chairman and managing director of Brown Bros. & Co. Ltd., Rosebank Ironworks, Edinburgh, has been awarded the Churchill Gold Medal by the Society of Engineers, 17 Victoria Street, London, S.W.1, for his part in bringing the Denny-Brown ship-stabilising gear into practical application.

Mr. W. D. Wilson, M.I.P.E., has been elected to the Board of Newman Industries Ltd., Yate, Bristol. He will continue in his present executive capacity as general manager of the company's Grantham Works.

Mr. K. A. Zandstra, A.M.I.E.E., technical sales manager for high frequency heating equipment in the Industrial Division of Philips Electrical Ltd., recently completed 25 years' service with the Organization.

BUSINESS NOTES

Newage (Canada) Ltd. has moved into a new factory at Bestobell Road, Queen Elizabeth Way, Toronto 14, Ontario, Canada.

Chemical Engineering (Wiltons) Ltd. has changed its address to Cheadle Heath, Stockport. Tel. Gatley 5231.

The National Industrial Fuel Efficiency Service has now been established in headquarters at 71/72 Grosvenor Street, London, W.1. Tel. HYDe Park 9706.

The Electrical Branch of the Factory Department of the Ministry of Labour is now at 40/41 York Terrace, Regents Park, London, N.W.1. Tel. MUSeum 5030.

Holden & Brooke Ltd., Sirius Works, Manchester 12, announce that following the merger with Frank Pearn & Co. Ltd., they will be now sole manufacturers and suppliers of the Pearn pumps.

Crone & Taylor Ltd., Sutton Oak, St. Helens, Lancashire, have formed two subsidiary companies, Crone & Taylor (Engineering) Ltd. and Crone & Taylor (Fertilisers) Ltd., to deal with the manufacturing business of the Company.

Ashmore, Benson, Pease & Co. Ltd., Stockton-on-Tees, have concluded an agreement with General American Transportation Corporation, Inc., Chicago, Illinois, U.S.A., to manufacture the Wiggins "Hidek" and "Lodek" floating roof structures for the petroleum and petro-chemical industries.

The Hawker Siddeley Group has purchased Canadian Steel Improvement Ltd., of Etobicoke, North Toronto, Ontario, Canada.

Scottish Machine Tool Corporation Ltd. has opened a district office at 2 Sir Harry's Road, Edgbaston, Birmingham 5. Tel. Calthorpe 2541.

Matling Ltd., Wolverhampton, a subsidiary company of A.B.C. Coupler and Engineering Co. Ltd., Wolverhampton, has opened new offices and showrooms at 28 Caxton Street, London, S.W.1. Tel. ABBey 6652.

J. P. Udal, Interlock Works, Court Road, Birmingham, have acquired an interest in Industrial Guarding Equipment Ltd. Close co-operation in the export field is contemplated.

A. Luson & Sons Ltd., Park Royal, London, N.W.10, has changed the name of the Company to Gem Brushes (Luson) Ltd. Mr. F. G. H. Foreman and Mr. E. Grosz, A.M.I.Mech.E. have been elected to the Board.

The Admiralty Gunnery Establishment has moved to Southwell, Portland, Dorset. The Admiralty Research Laboratory remains at Teddington, Middlesex.

Booth, Macdonald & Co. Ltd., Christchurch, New Zealand, have concluded an agreement with David Brown Tractors (Engineering) Ltd., Meltham, Yorkshire, for the assembly and, later, the manufacture of components for David Brown implements.

The Institution of Production Engineers announce that the Institution's new address is now 10 Chesterfield Street, London, W.1. Tel. GROsvenor 5254/9.

The Denis Ferranti Co. Ltd.'s Transformer Works at Royton, near Oldham, Lancs., is nearing completion. It will enable transformers up to the very largest sizes and highest voltages to be built. Entirely new methods of handling during construction will be employed. Aluminium alloy construction and the employment of latest building techniques have made possible to secure a completely uninterrupted floor space of approximately 30,000 square feet.

Ewbank and Partners Ltd., 10 Grosvenor Place, London, S.W.1, have formed an associate company, Ewbank and Partners (Canada) Ltd., with headquarters in Toronto, Ontario, Canada. It will be under the general direction of Mr. J. T. Moore, director of the parent company and until recently chief engineer of The English Electric Co. Ltd. Crippen Wright Engineering Ltd., Vancouver, B.C., whose President, Mr. C. E. Crippen, was previously chief design engineer of B.C. International Engineering Company and was responsible for the design of the Kemano power project of the Aluminium Company of Canada, will closely co-operate with the new company. Mr. C. H. P. Ewbank, chairman of Ewbank and Partners Ltd., has been elected to the Board of Crippen Wright Engineering Ltd.

The Projectile & Engineering Co. Ltd. has formed a separate sales organisation, Peco Machinery Sales (Westminster) Ltd., 28 Victoria Street, London, S.W.1. Tel. ABBey 1793/5. Mr. A. J. Chambers, M.B.E., M.I.P.E., managing director of Projectile & Engineering Co. Ltd., has been elected chairman, Mr. M. Freund, M.I.Mech.E., and Dr. E. Gaspar, A.M.I.Mech.E., have been elected directors of the new company. Mr. L. W. Lees has been appointed sales manager.

The Birmingham Exchange and Engineering Centre, which will be Britain's only permanent engineering exhibition, will be opened by Lord Bennett on June 17th. More than 200 firms have booked all available space for their exhibits.

Edward Wilcox & Co. Ltd., Manchester, manufacturers of the Slydlok range of fusegear, have opened their London office at Fulwood House, Fulwood Place, London, W.C.1. Tel. CHAncery 2206.

Brook Motors Ltd., Huddersfield, have moved their Glasgow office to Carlton House, Blythswood Square, Glasgow C.2. Tel. Central 1045.

Macrome Ltd., Aldersley, Wolverhampton, announce the appointment of Mr. John S. Dick to the position of Scottish area manager. He will operate from the new Macrome office at Central Chambers, 11 Bothwell Street, Glasgow C.2.

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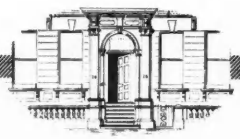

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Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17, have further co-ordinated the heating and welding activities of the company. The engineering sections dealing with all forms of h.f. heating (induction furnaces, dielectrics heating, etc.) as well as resistance heating using sheathed tubular elements have been combined with the welding engineering department, under its chief engineer, Mr. C. F. Saunders.

Wickman Limited announce the appointment of Mr. G. C. Bateman as direct factory representative for Lidkopings Mekaniska Verkstads Aktiebolag, Lidkoping, Sweden, and Ulvsunda Verkstader Aktiebolag, Ulvsunda, Stockholm, in the United Kingdom and other countries.

Mr. Bateman who is a grinding machine specialist will be located at Wickman Limited, Factored Machine Tool Division, Fletchamstead Highway, Coventry.

Wickman Limited have appointed Mr. B. Heaven as their own sales specialist for Lidkoping Centreless Grinding Machines, etc. and U.V.A. Internal Grinding Machines for their exclusive territory of the United Kingdom.

The Dunlop Rubber Company Ltd. has acquired for £750,000 the entire share capital of Brynmawr Rubber Ltd. from Enfield Cables Ltd.

The factories at Brynmawr and Cwmavon will provide the Dunlop Rubber Company with additional space for the manufacture of products other than tyres, and, for the time being, existing production will be continued.

Ardleigh Engineering Ltd., Langham Lane, Langham, Colchester, has been formed as a new company, to provide engine speed governors and other control equipment for engine builders. At present four main types are offered for constant or variable speed engines.

W. Canning & Co. Ltd. have opened new premises at One South Parade, Shalesmoor, Sheffield 3. Tel. No. Sheffield 24101.

The Electrical Division of Measurement Ltd. and Aspec (London) Ltd. have been merged and will operate as a new Division of Parkinson & Cowan Ltd. under the name Parkinson & Cowan Instruments (Incorporating Aspec) a Division of Parkinson & Cowan Ltd., 7 Fitzalan Street, London, S.E.11.

Associated British Engineering Ltd. have moved their registered offices to 9/10 Cavendish Square, London, W.1. Tel. No. Langham 8351/3. The London sales offices of The Bergius Co. Ltd., Henry Meadows Ltd., H. Widdop & Co. Ltd. and A. C. Morrison (Engineers) Ltd., which are members of the Associated British Engineering Group of Companies, will be situated at the same address. The Parsons Engineering Co. Ltd. have moved their London office to the same address.

Burton, Griffiths & Co. Ltd., of Kitts Green, Birmingham 33, have been appointed Sole Selling Agents in Great Britain and Northern Ireland for the sale of " Sparcatron " Equipment.

The " Sparcatron " technique of machining metals by spark discharge makes available for the first time a means for working hard metals which cannot be machined by edge tools, or even be readily ground by abrasive wheels. There are few metals, however hard or tough, which cannot be machined by the " Sparcatron " method which makes it possible to execute all standard machining operations such as cutting-off, sawing, turning, milling, hobbing, broaching, drilling, trepanning and grinding. Present industrial applications are mainly confined to operations for the production of holes and forms where the component can be held stationary. Development of external threading and external grinding for general use is being rapidly pursued.

However, machining operations can be carried out which were hitherto impossible, such as the drilling of curved holes and the sinking of holes of whatever outline required.

In application " Sparcatron " is performing operations throughout the whole range of the tool-making industry, including making and opening wire and extrusion dies, blanking dies, and forging dies, the re-sinking of stamping die forms, machining of form tool shapes, gauge machining and magnetic fabrication and a multitude of special work involving complicated shapes in hard and fragile materials and previously unsolved machining problems in the majority of materials capable of conducting an electric current.

Burton, Griffiths & Co. Ltd., working in close co-operation with " Sparcatron " Limited, are maintaining a development and application section which is also available for demonstration to potential users of the " Sparcatron " technique of machining metals.

" Sparcatron " Equipment will be exhibited by the makers—Impregnated Diamond Products Limited on Stand No. 25 at the forthcoming Gauge and Toolmakers Exhibition at the New Hall, Vincent Square, London, S.W.1 during the period of the Exhibition May 17th-28th, 1954. A representative of Burton, Griffiths & Co. Ltd., will be present to give further information to those interested.

J. Stone and Company Ltd. of Deptford and Charlton, have bought the engineering interests of Chance Brothers Ltd. These interests include the manufacture of Sumo electrical submersible pumps, marine lighting and lighthouse equipment and fog signalling apparatus, and Austinlite automatically-controlled electric generating plant, switches and instruments.

A new company will be formed, which it is intended shall be called Stone-Chance Limited, with Mr. Bryan Preston, deputy chairman of J. Stone (Holdings) Ltd., as chairman, and Mr. John Raymond, who has up to now been managing director of Chance Brothers, as managing director. The two principal subsidiary companies, Sumo Pumps Limited and Austinlite Limited, will continue to handle pumps and electrical equipment.

The reason for the sale is that the business carried on by the Engineering Division of Chance Brothers has over the years become remote from glass-making, and the sale follows logically the separation last year of the management of the Division from those dealing with glass manufacture.

Chance Brothers Limited will continue to manufacture the glass products for which the firm is renowned, with Dr. W. M. Hampton, formerly technical director, as managing director, and Mr. C. J. S. Newman as deputy.

The formation is announced of the **British S.G. Iron Producers' Association** from amongst the licencees in Great Britain and Northern Ireland of the process under British Patent No. 630,070 and others for producing Spheroidal Graphite Iron Castings. The Association has been brought into being to facilitate the exchange of information on the manufacture of this new material, and to encourage its use in the large diversity of applications for which it is suitable. It is also co-operating with the British Standards Institution in the preparation of a specification.

Mr. P. A. Russell and Mr. W. R. Cooper have been elected Chairman and Vice-Chairman respectively, and Mr. C. Gresty has been appointed Hon. Treasurer. Over 80% of the active producers of S.G. Iron in this country are founder members of the Association. The Secretariat and offices are at 94/98 Petty France, London, S.W.1.

The members are taking part in the Exhibition organised by The Mond Nickel Co. Ltd., to be held on May 25th-27th at Park Lane House, London, W.1, which, it is hoped, will be attended by a large number of engineers and others who wish to obtain full information on the many uses of S.G. Iron.

The Third post-war Convention of the British Institution of Radio Engineers is being devoted exclusively to industrial electronics. The main theme is to show how electronics can increase qualitative and quantitative production, and production efficiency in all branches of industry.

The Convention will be held in the University of Oxford from 8th to 12th July and delegates will be resident in Christ Church.

Sir John Cockcroft, K.C.B., C.B.E., F.R.S. (Director of Research, A.E.R.E., Harwell) will deliver the Institution's Clerk Maxwell Memorial Lecture in the Clarendon Laboratory, Oxford, on Thursday, 8th July, at 8 p.m.

In addition, over 30 papers will be presented during the Convention, covering computors for industry and commerce, industrial X-ray equipment and the use of ultrasonics, nucleonic instrumentation, transducers in industrial production, and the various applications of electronics to process control.

After the opening of the Convention by Mr. William E. Miller, M.A.(Cantab.), (President of the Institution), the Chair at each session will be taken by the following :

Session 1 : Industrial Applications of Electronic Computors. L. H. Bedford, O.B.E., M.A., B.Sc. (Past President) Chief Engineer, English Electric Company, Luton).

Session 2 : Industrial Applications of X-rays and Sonics. H. G. Foster, M.Sc., M.Brit.I.R.E. (Managing Editor, " Electronic Engineering ").

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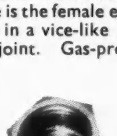

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Session 3 : Nucleonic Instrumentation and Application.
N. C. Robertson, C.M.G., M.B.E., M.Brit.I.R.E. (Managing Director, E. K. Cole Ltd.).

Session 4 : Electronic Sensing Devices (Transducers).
Professor E. E. Zepler, Ph.D. (Vice-President) (Professor of Electronics, University of Southampton).

Session 5 : Process Control.
J. L. Thompson (Vice-President) (Managing Director, J. Langham Thompson Ltd.).

The Chair at the final session on " Industrial Aids to Production " will be taken by Sir Walter Puckey.

A detailed programme and reservation forms may be obtained from The Secretary, The British Institution of Radio Engineers, 9 Bedford Square, London, W.C.1.

FOURTH MECHANICAL HANDLING EXHIBITION

The Minister of Supply, Mr. Duncan Sandys, M.P., will open the fourth Mechanical Handling Exhibition and Convention at Olympia, London, on June 9th.

All space has been let for the Exhibition (June 9-19), the world's largest and most comprehensive display of labour-aiding and ancillary equipment, 75 per cent of which will be working.

The Convention programme is now complete, as follows :—

Thursday, June 10, 2.30 p.m.
(1) Work Study and the Materials Handling Engineer.
Speaker : C. G. Chantrill.
Chairman : W. J. Dimmock, A.M.I.Prod.E.

Friday, June 11, 11 a.m.
(2) Bulk Handling by Transporters.
Sponsored by Association of Crane Makers.
Speaker : P. B. Tucker.
Chairman : H. R. Mills, Ph.D., B.Sc.(Eng.), M.I.Mech.E.

2.30 p.m.
(3) Heavy Type Mobile Cranes.
Sponsored by Association of Crane Makers.
Speaker : A. Hallsworth.
Chairman : R. M. Wynne-Edwards, D.S.O., M.I.C.E.

Saturday, June 12, 11 a.m.
(4) Bridging the Handling Gap.
Sponsored by Institute of Materials Handling.
Speaker : John Bright.
Chairman : R. T. Pirie, D.F.M., B.Sc.(Eng.).

2.30 p.m.
Open Forum " In Search of Better Handling."
A team of experts will answer " Any Questions."
Sponsored by Institute of Materials Handling.
Team : A. R. E. Arnot, B.Sc.(Eng.), A.M.I.E.E.
D. C. Boak, A.M.I.Mech.E., A.M.I.Prod.E.
Don Kelsey.
H. P. Mott, A.M.I.Prod.E.
A. F. Much, A.C.A.
E. G. Whitaker, M.Inst.T.
Chairman : W. J. Brown.

Monday, June 14, 11 a.m.
(6) Belt Conveyors : application of all types to mechanical handling.
Sponsored by Mechanical Handling Engineers' Association.
Speaker : T. R. Mackie.
Chairman : J. Johnston.

2.30 p.m.
(7) Notes on some unusual handling problems.
Sponsored by Mechanical Handling Engineers' Association.
Speaker : R. L. Sauvée, A.M.I.Mech.E.
Chairman : Sir Norman Kipping, J.P.

Tuesday, June 15, 2.30 p.m.
(8) Long Aerial Ropeways as applied to Mineral Development.
Sponsored by Aerial Ropeways Association.
Speaker : Reginald H. Pearson.
Chairman : C. W. D. Rowe.

Wednesday, June 16, 11 a.m.
(9) Philosophy of Cargo Handling.
Sponsored by International Cargo Handling Co-ordination Association.
Speaker : Cdr. A. C. Hardy, B.Sc.(E.), M.I.N.A., F.R.G.S., A.M.I.Mar.E.
Chairman : Rear-Admiral A. L. P. Mark-Wardlaw, M.I.N.A., M.I.Mech.E., M.I.Mar.E.

2.30 p.m.
(10) Economics of Modern Materials Handling with Industrial Trucks.
Sponsored by Industrial Truck Manufacturers' Association.
Speaker : R. B. Lister.
Chairman : Gen. Sir Ouvry L. Roberts, G.C.B., K.B.E., D.S.O., M.A.

Thursday, June 17.
Second European Mechanical Handling Conference (Private).

Friday, June 18, 11 a.m.
(11) Safe use of Fork Lift Trucks in Industry.
Speaker : A. C. Cooper.
Chairman : L. J. Hoefkens.

2.30 p.m.
(12) Process Mechanisation with the aid of spiral Conveyors.
Speaker : J. M. Beskine, B.Sc.(Eng.).
Chairman : Professor J. M. Coulson, M.A., Ph.D., D.I.C.

The Exhibition and Convention, which are held biannially, are organised by " Mechanical Handling," Dorset House, Stamford Street, London, S.E.1, with the support of trade associations.

THE NEW PHILIPS UNIVERSAL CLARIFIER

One of the major problems of wet grinding is that of keeping the coolant clean. It is obvious that a super-finish can never be attained on the work if small particles of swarf and grinding-wheel dust remain suspended in the coolant.

Grinding-machine manufacturers provide their machines with large coolant settling tanks in the hope that the swarf and sludge will settle to the bottom of the tank and remain there while the pump draws fresh coolant from a higher level. While the machine is in operation, however, the action of the pump causes a turbulence in the tank which prevents the smaller particles from settling. Furthermore, the settling tanks must be emptied and cleaned out regularly which, besides being costly due to the frequent renewal of coolant, is also an unpleasant task and is, therefore, not carried out as often as would be desired.

To overcome these problems The Industrial Division of Philips Electrical Ltd. have recently added a series of Universal Clarifiers to their present range of magnetic and mechanical filtration equipment.

The new Philips Universal Clarifier is designed to remove all contamination, including the fine suspended particles of swarf and grinding-wheel dust, from any type of coolant. It is entirely automatic in operation and the only attention required is that the sludge box be periodically emptied.

The Philips Clarifier can be fitted to all types of grinding machines. Ample coolant storage capacity is provided, so that it is possible to dispense with normal settling tanks by fitting the machine coolant pump into the compartment provided on the clarifier.

The polluted coolant, leaving the workpiece, flows into a trough of special filtering material carried on an endless wire-mesh conveyor. The filtering medium retains all swarf and abrasive dust on its surface, but is sufficiently porous to permit a free and uninterrupted flow of filtered coolant into the sump of the clarifier whence it is returned by pump to the grinding head. As the filtering medium becomes saturated the fluid level in the trough rises and lifts a float. At a pre-set height this float operates a micro-switch and an electric motor moves the wire-mesh conveyor forward to provide a clean filtering trough and to automatically deposit the contaminated filtering medium into an open sludge box.

There are four standard models having capacities of 500, 1,000, 1,800 and 3,000 gallons per hour. A larger model, now being designed, will accommodate a coolant flow of 4,800 gallons per hour.

The approximate flow rates given above are for normal soluble-oil coolants and depend on the stock removed and viscosity of the coolant.

A NEW ULTRA-LIGHT WEIGHT FIRE PUMP POWERED BY GAS TURBINE

For many years Sigmund hydraulic engineers have applied their efforts to the design of a fire pump which can give the fire fighter the essential qualities demanded by the vital urgency of the job—light weight, small bulk, easy and quick starting, fast priming, and absolute dependability at all times. Each new advance in pump design has been incorporated from accumulated experience in succeeding models of Sigmund fire pumps to achieve the ideal unit.

Now the advances in gas turbine design and development by the Rover team of engineers have been brought together with Sigmund hydraulic experience to overcome every major problem confronting the fire pump designer.

By combining the advantages of the latest Rover light weight gas turbine with those of the Sigmund high speed centrifugal pump, the new Sigmund Rover 1S/60 unit gives outstanding advantages not obtainable previously by any equivalent portable petrol driven fire pump.

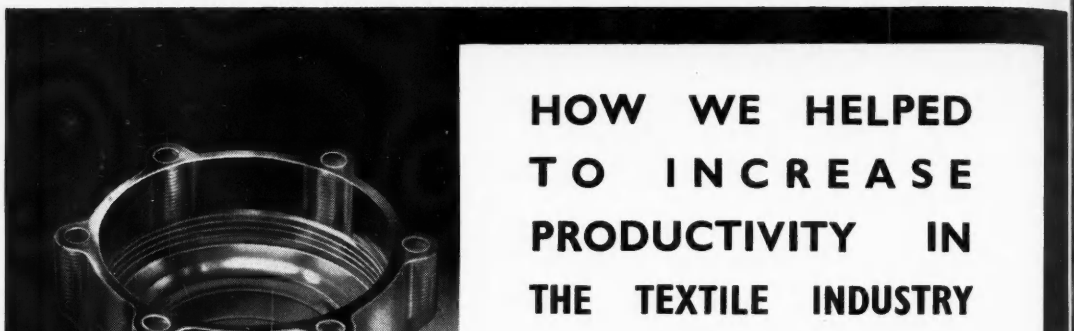
The following are some of the more noteworthy features of this unit :—

1. *Big Performance*—equivalent to a heavy trailer pump.
2. *Light weight*—Note these comparisons :—

Type	Imperial G.P.M.	Weight lbs.	H.P.	Lbs/H.P.
Light Unit	120	490	20	25
Medium Unit	350	310	30	10
Heavy Unit	500	1754	80	22
Sigmund Rover ..	500	215	60	3·6

3. *Small Bulk*—10·2 cu. ft. against an equivalent pump requiring 87 cu. ft.
4. *Quick Starting*—from cold in 15 seconds.
5. *Quick Priming*—at a minimum of 1 foot per second and can lift up to 24 feet.
6. *Choice of Fuel*—efficient performance on Diesel, paraffin, petrol or any distillate fuel.
7. *Twin discharge branches.*
8. *Grouped starting and priming controls.*
9. *Grouped instrument control panel.*
10. *Frame of braced tubular steel construction*—giving maximum strength with lightness.
11. *The most compact and lightest 500 g.p.m. fire pump yet made.*

The full range, available shortly, includes both portable and stationary types, and in addition to fire fighting duty, these units can be advantageously applied to a diversity of applications in many fields.



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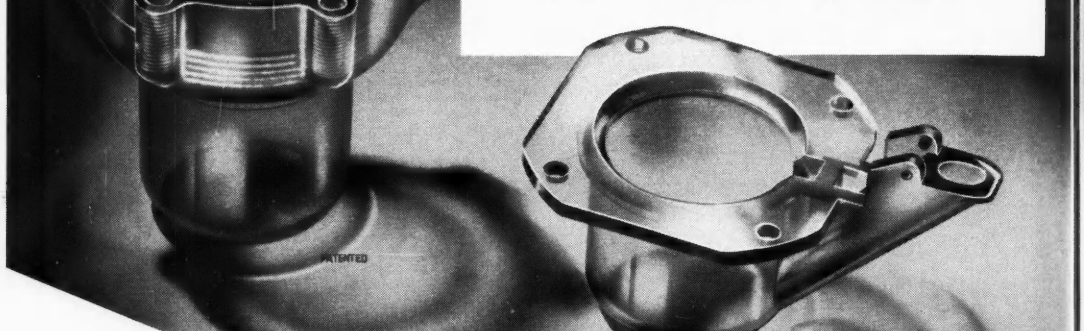

CASE HISTORY OF AN OIL BATH

A manufacturer of textile machinery conceived the idea that if the bases of spindles could be immersed in oil the time wasted in stopping the machines for oiling purposes could be reduced, thus considerable saving in time would result.

Such an oil bottle would need to be virtually unbreakable, unaffected by oil, capable of being securely fastened to the machine and able to withstand high-speed machine vibrations.

He got together with Elliott designers and the plastic bottle illustrated above (stage 1) was the result. It has been an outstanding success.

Later, the same customer asked for a bottle which could be refilled without stopping the machinery at all, and the bottle illustrated (stage 2) was produced. If *you* have a plastic problem we are always happy to help you. Remember we are one of the largest independent producers of mouldings in plastics by compression, transfer or injection.

Some of the Machines in our injection moulding shop

HEAD OFFICE & WORKS:
E. ELLIOTT LTD., 315 SUMMER LANE, BIRMINGHAM, 19
Four Branch Factories *Tel.: Aston Cross 1156-7-8-9*

E. Elliott LIMITED
THE MOULDERS WITH THE ENGINEERING BACKGROUND

Oil companies will find these pumps particularly suitable for booster stations, pipelines carrying distillate fuels and certain gases, and for foam generation and other duties.

The Sigmund 1S/60 pump can be supplied mounted on a four wheeled drive jeep, or Land Rover, providing a powerful portable pumping unit capable of travelling over the roughest country to the most isolated situations where the pump is required to operate.

In addition to fire protection duty on land, the Sigmund Rover 1S/60 is suitable for shipboard service, and can be operated on deck to give prompt and efficient protection in case of fire at sea.

Further details of this new ultra-light weight fire fighting pump can be obtained on application to Sigmund Pumps Ltd., Team Valley, Gateshead 11.

NEW PAINT FOR SONIC PLANES

A new high-speed paint for the latest jet fighters and bombers which will not peel off in flight near the speed of sound is being developed by a British company. It has already been tested on the tail of the latest Air Force operational aircraft and will shortly be used full-scale on one of the latest jet machines.

The paint—or finish—is based on a newly-developed resin which enables it to withstand great temperatures and to "stick" to the fuselage despite the very great friction which is generated by the air rushing past aircraft flying at high speeds. There is a tendency for existing finishes to peel off under these conditions.

The temperature rise due to skin friction at these high speeds is said to be roughly the speed of the aircraft divided by 100 and squared—so a plane flying at 700 mph will heat up about 50°C (7×7) above the local air temperature. This heat rise may tend to soften the paint, which is then whipped off by the blast of air rushing past the aircraft. Rain or hail has also to be taken into account; at high speed, it hits the aircraft like a shot from a gun.

The new finish, developed by Cellon, is unaffected by temperatures up to 400° F, which is the heat possible near the exhausts of the latest jet engines. It is also resistant to jet fuels, lubricants and hydraulic fluids.

The new finish has been extensively tested at Cellon's factory near London. In one experiment to investigate its suitability for naval aircraft, a panel covered with the finish was placed on the roof of the factory and sprayed with salt-water three times a day. It has been scratched to test its toughness, bent in hot and cold tanks to test its flexibility and put in an "accelerated weather machine." This sprays it with sea-water and alternatively subjects it to blistering ultra-violet light.

The new finish is a catalyst air-drying type based on the new epoxy-type resins. It is used in conjunction with a light-weight primer, so that only two coats are necessary—thus ensuring that weight is kept to the minimum.

Research into new paints not only gives new aircraft a completely adequate protective coating—it also gives them the best possible finish aerodynamically. In fact, if one jet fighter is 20 miles an hour faster than another in combat, the pilot may owe his victory to the man who gave his plane its "finish."

The importance of paint was drummed home in the early years of the last war. A captured German fighter was found to be 16 mph faster than the *Spitfire*—and experts were given orders to bring the *Spitfire* up to par. They tried everything without success—and then hit on the paint solution. By using a thinner smoother paint, they cut down drag over the wings and the plane had the 16 mph more speed that mattered.

BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 2, Park Street, London, W.1.)

Hook Spanners, Peg Spanners, Coupling Wrenches and the Related Slots, Holes and Horns. B.S. 2090 : 1954. These spanners or wrenches are indispensable where circular nuts of various forms are used as in motor cars, public transport, machine tools, etc.

A section provides for wrenches used on hose couplings. Price 5/-.

Summary of face-to-face dimensions of flanged ferrous valves for the petroleum industry. B.S. 2080 : 1954 provides for the petroleum and petroleum equipment industry a convenient comparison of face-to-face and end-to-end dimensions of flanged ferrous valves with plain face, raised face or ring joint end flanges, as specified in the following British Standards, with their counterparts specified in American Standards, and with some other valves not yet standardized :—

B.S. 1414—"Flanged steel outside-screw-and-yoke wedge gate valves for the petroleum industry."
B.S. 1570—"Flanged steel plug valves for the petroleum industry."
B.S. 1655—"Flanged automatic control valves for the petroleum industry (face-face-dimensions)."
B.S. 1735—"Flanged cast iron gate valves, Classes 125 and 250 for the petroleum industry."
B.S. 1868—"Flanged steel check valves for the petroleum industry."
B.S. 1873—"Flanged steel globe valves for the petroleum industry."

In addition to the tables listing dimensions in inches, companion tables are given listing the metric equivalent in millimetres. Price 6/-.

Hose Couplings for Petrol, Oil and Lubricants ($\frac{1}{4}$ in. to 4 in. nominal size). B.S. 2464 : 1954 applies to the reduced bore type of couplings and adaptors for $\frac{1}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3 and 4 in. hose, for use at pressures not exceeding 100 lb/sq. in.

Two forms of screw threads have been specified for the couplings: Whitworth (B.S.P.) threads in accordance with B.S. 84 and American threads in accordance with ASA specification B.33.1 ($\frac{1}{4}$ in. to 2 in.) and with Federal Standard Stock Catalogue ZZ-H-466b (November 1935) ($2\frac{1}{2}$ in. to 4 in.). Details of these American hose coupling threads are given in the appendices. These latter threads have been specified to ensure that the couplings connect with oil equipment screwed in accordance with API.STD. 5L and 6A.

These couplings may be secured to the hose by clamps, by clips, or by other suitable means.

This standard deals with materials, dimensions, workmanship, marking and hydrostatic testing of the couplings. Illustrations of the couplings and full dimensional particulars are given. Price 7/6.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

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SITUATIONS VACANT

ARMSTRONG SIDDELEY MOTORS LIMITED, have vacancies for Technical Assistants for research and experimental work on aircraft gas turbines; particularly on compressors, turbines and aerodynamic flow problems. Engineering Degree, HNC or equivalent necessary. Write in detail to Reference GWB, Personnel Manager, **Armstrong Siddeley Motors Ltd.,** Coventry.

EXPERIENCED DESIGN DRAUGHTSMAN required for permanent, interesting work on small mechanisms. North London area. A.E.S.O. scale to commence. Write in confidence giving details to Box No. G.C.5.

CAPACITY AVAILABLE

Scottish Area

ELECTROPLATING AND HEAT TREATMENT. A large modern factory in Scotland, fully equipped with the latest specialised plant has capacity available to undertake electroplating. Cadmium, Copper, Nickel, Tin, Silver, Chromium, Anodising. Also Heat Treatment: Nitriding, Pack Carburising, Liquid Carburising, Salt Bath Heat Treatment, Controlled Atmosphere Heat Treatment, Copper Brazing—Continuous Process under controlled atmosphere conditions. All to A.I.D. standards. Write Box S.A.1.

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Upper Part of Modern Office Building available.

Total nett floor area of 19,000 sq. ft. with

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of 11,500 sq. ft. and balance in 1958. TO LET for a term of 35 years at rental of **£13,150** p.a. exclusive, rising to **£15,000** p.a. exclusive. Central Heating, lift, etc. For full particulars please apply to Box No. L.S.5.

MISCELLANEOUS

RECONDITIONED EX-ARMY HUTS, and manufactured buildings. Timber, Asbestos, Nissen Type, Hall Type, etc. All sizes and prices. Write, call or telephone—**Universal Supplies (Belvedere) Ltd.,** Dept. 50, Crabtree Manorway, Belvedere, Kent. Tel.: ERITH 2948.

WANTED.—Copies of the March, 1953 issue of "The Engineers' Digest" urgently required. Also Jan., 1949, June, 1950, and Dec., 1951, issues at 3/6 per copy.—Subscription Dept., 120, Wigmore Street, London, W.1.

LATEST INDUSTRIAL LITERATURE

1. Universal Hobbing Machines. Full details, including specifications and capacities, are given in a well produced and illustrated 12-page brochure, of two universal hobbing machines, designed for the production of spur gears, right- or left-hand helicals, straight or helical splines with involute or straight sides, serrations, ratchets, worms and wormwheels, and intricate generated profiles.

With these machines, which are made to the highest standards of accuracy, either climb or normal hobbing methods can be used, and their exceptional rigidity permits high output rates with good commercial accuracy.

2. Unit Grinding Head and Truing Device. Equipment, which has been designed to permit rapid and accurate grinding of a wide variety of machine slides with a single setting of the head, is described and illustrated in a 4-page leaflet.

The device is applicable to both vertical and horizontal heads, and only one setting is necessary for the truing of the grinding wheel, to assure a correctly coned and perfectly trued wheel. Practically any surface-grinding or planing machine, some vertical boring machines, and milling machines can be adapted for use with this device.

3. Industrial Solenoids. A comprehensive range of industrial solenoids is listed and illustrated in a 16-page catalogue. These solenoids have been designed to produce the maximum power for their size, and it is claimed that some of the units described are up to 50% more powerful than other known comparative types.

Frames and plungers are manufactured for stock. While stocks of coils for normal voltages are carried, coils for the less popular voltages are wound and fitted to stock frames and plungers, so that deliveries of reasonably large quantities can be effected quickly.

4. Direct-Reading Fault Localisers. A series of instruments, designed for locating the positions of earth faults on power cables, is described and illustrated in a 4-page leaflet.

The range includes a low-tension localiser, suitable for use at voltages up to 600, giving at this voltage an accuracy of 0·1%, on faults up to 20,000 ohms resistance ; a high-tension instrument, for investigating faults at test voltages up to 50 kV ; and a capacity and inductance fault localiser, for use on open-circuit faults, together with a self-contained Wheatstone bridge, which can be applied for locating faults by the Murray and the Varley loop tests.

5. Universal V-Belt Pulleys. Details and specifications of a patented, universal V-belt pulley are contained in a 4-page pamphlet. By virtue of its design, this pulley offers several advantages, among which may be mentioned the following :—No loose bolts or bushings are required for joining the segments ; pulleys with any desired number of grooves and pitch-circle diameter may be obtained immediately from stock ; every type of segment is adjustable to several pitch-circle diameters and fits three different belt sizes ; and every type of segment allows for changes of speed.

6. Mechanical Continuous Loader. Details are given in a folder of a mechanical continuous loader of unusual design, for the handling of loose materials, including sand, gravel, coal, coke, chemicals, cement, slag, and grain.

The loader gives a continuous flow of materials at a rate of 30 to 50 cubic yards per hour. It is extremely manoeuvrable and portable, and can be controlled by only one man. Furthermore, it is designed for continuous operation under rugged site conditions, and is fully protected against weather and extraneous materials.

7. Shaft Seals. Specifications of a wide range of seals for shafts rotating at high speeds are given in a well produced 14-page catalogue.

The sealing nose of these mechanical face-type seals can be of special bronze or carbon, according to the application, whilst the diaphragm can be in silicone rubber, if necessary. The seal carrier can be of the normal or flange type, to suit all applications. These seals are practically wearless, do not cause shaft wear, are self-adjusting and leakproof, do not generate heat, and do not absorb power.

8. Pneumatic Press Brake Guard. A pneumatic press brake guard, designed to give maximum efficiency in operation, with the highest degree of safety, is described in a neat and well illustrated 8-page brochure.

Operation of both guard and machine is effected by one depression of the clutch pedal. Controlled by a simple, yet effective, pneumatic system, the guard apron first descends to a set tolerance above the workpiece, and prevents further access to the tool space before the clutch can be engaged. The guard is locked in the down position under air pressure before the clutch engages, and starts to rise again immediately the tools touch the workpiece, which is thus formed without guard interference.

9. Steel-Framed Buildings. A range of steel-framed buildings, with optional components, is described and illustrated in an 8-page brochure. The span of these buildings ranges from 30 to 60 ft, with heights to eaves of between 8 to 15 ft. Lengths are in multiples of 12 ft 6 in. Lean-to extensions, up to 20 ft, are available.

The buildings are sheeted with asbestos cement, corrugated sheets, or galvanised steel, as required, and perspex roof-lights can be supplied to suit the sheeting. Various types of asbestos-cement or galvanised-steel ventilators can be supplied, with or without power-operated extractors.

10. Hacksaw Blades. A comprehensive range of hacksaw blades is described and illustrated in a neatly presented and handy little 16-page booklet.

In addition to specifications of blades for various applications, the booklet contains many useful hints on their correct choice and application for the varying needs of the workshop. Time spent in studying the information given, so as to select the right blade for the required job, will be amply repaid in improved blade life and reduced cost to the user.

11. Lifts. Hand and electric lifts are described and illustrated in a broadsheet, which also gives details of self-landing delivery hoists, sliding-door gear and components, and wood rolling shutters.

The hand lifts embody a self-acting brake, or self-sustaining action, thereby dispensing with the need for a separate rope. The electric lifts are available with either pushbutton, car-switch, or hand-rope operation, and their usual speeds are from 50 to 200 fpm.

12. Industrial Brushes. Details of a representative selection of brushes for industrial, commercial, and domestic use are contained in a neatly produced and illustrated 12-page brochure.

The selection ranges from brushes for scouring and cleaning tubes and pipes, to brushes for 20-mm automatic cannon, and from brushes for typewriters to denture brushes. Motorised brushes are also featured, while nylon-filled brushes and wool mops can also be supplied.

13. Revolving Centres. Details and prices of a range of revolving centres for lathes are given in a pamphlet. These centres, which are hardened, tempered, and ground to a tolerance of 0·0003 in., are made of the highest-quality Sheffield steel, and are fitted with specially tested bearings.

14. Precision Measuring Instruments. A range of fully guaranteed precision measuring instruments, manufactured to British Standard Institute's limits, is described and illustrated in a 16-page booklet. The instruments described include vernier height gauges, universal vernier bevel protractors, vernier depth gauges, knife-edge vernier calipers, sine bars, vee blocks, screw-pitch gauges, etc.

All vernier instruments are supplied in suitable cases.

15. Motor-Driven Diaphragm Pump. Details and specifications of a motor-driven diaphragm pump, specially designed for the chemical and allied industries, and suitable for handling a wide range of chemicals and sludges, are given in a pamphlet. These pumps, which are of robust construction and self-priming, contain no packing, and are fitted with rubber bearings and corrosion-resistant hose connections. The maximum static discharge head is 25 ft, the maximum suction lift is 10 ft, and the nominal rate of discharge is 8 Imp. gallons per minute.

A supplementary leaflet describes a hand-operated diaphragm pump of similar design.

16. Automatic Plate Valves. In an excellently conceived, produced, and illustrated 64-page publication, tables, diagrams, and exploded views of a wide range of automatic plate valves are given, together with details of their applications.

The range includes centrally guided valves, frictionless guided valves, high-lift valves, high-speed valves, and non-return valves.

17. Diamond-Impregnated Grinding Wheels. Details of a new diamond-impregnated grinding wheel, for the grinding and lapping of tungsten carbide, are contained in a folder, together with graphs of comparative performance.

As the result of rigid quality control throughout production, from the crushing and grading of the diamond to the final inspection, the new wheel is reported to give a faster cutting rate and better finish, long life, and freer and cooler cutting, with strength to resist grooving and the ability to maintain a high cutting speed.

18. Structural Design in Aluminium. To assist designers in the use of aluminium for structural purposes, interesting data are provided in a well produced and illustrated 40-page handbook.

Sections include concise and useful information on alloys, safety factors, design of tension members, struts, and beams, connections, protection, types of sections, weight calculations, etc.

19. Friction Clutches. A 12-page brochure describes and illustrates a range of friction clutches for a wide variety of applications, including multi-plate clutches, air-operated friction clutches and brakes, reversing clutches, cone clutches, twin-disc power-take-off clutches, and centrifugal clutches.

Among other advantages claimed for these units are that they are absolutely dustproof, that they will not fire or spark, that they are suitable for any class of drive, that they are perfectly balanced, and that they will run in either direction without alteration in design.

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *ELECTRONIC POWER SWITCH*

In a new type of electronic power switch, the output waveform has rise and cut-off times of less than one microsecond. During a study of spark-recorder transformers, it was found that the usual cross-coupled thyratron power switches with two thyratrons had several disadvantages. For instance, they waste power, as one thyratron is conducting during the entire "off" period of the switch. The conventional circuit has now been modified so that the turn-off tube is self-extinguishing, and the undesired transient has been removed by the addition of a diode between the two thyratrons. The new design also provides an output voltage of rectangular waveform with negligible overshoot, leading- and trailing-edge times of less than 0·25 microsecond, and a wide duty-cycle range. The electronic switch comprises three valves—two thyratrons and a diode rectifier. A condenser is connected to the plate of the power-delivering thyratron through the diode, and to the plate of the turn-off thyratron through an inductance. The other side of the condenser is earthed. The condenser is normally charged when the circuit is in use. The switch is turned on by applying a pulse to the grid of the power valve; it is turned off by applying a pulse to the grid of the turn-off valve, which begins to conduct and discharges the condenser through the inductance, causing an oscillatory discharge. The thyratron, however, conducts in one direction only and current flows for only one quarter of a cycle; this suffices, however, to discharge the condenser completely. The rapidly decreasing condenser voltage appears on the plate of the power thyratron, thereby cutting off the flow of current through the thyratron and at the same time extinguishing the turn-off valve.

● *PRODUCTION OF LINE DRAWINGS FROM PHOTOGRAPHS*

A most interesting optico-electronic process has just been announced, which makes it possible to produce line drawings from photographs. In this process photographic transparencies are placed in an optical assembly between a cathode-ray tube with a moving spot, and a photo-multiplier tube. The signals resulting from scanning the picture are amplified and fed back to the intensity control of the cathode-ray tube and thus produce a picture on its screen. The negative feedback obtained in this way improves the tonal rendition of the picture. The same signals are also applied to another amplifier, and the resulting signal is used to control a monitor cathode-ray tube which reproduces the same picture. Altering the monitor for image processing is accomplished by introducing modifying circuits between the photo-tube and the monitor. This freedom of modification of the picture on the monitor is the essence of the system. The sharpening of tone transitions for the purpose of enhancing contours is accomplished by modifying the wave-form of the signal applied to the monitor oscilloscope. This is effected by adding on electrically an enhancing signal—the negative of the second derivative—obtained from the original signal. Mathematical analysis indicates that a first approximation to a correctly focused picture is obtained when this process is applied to an incorrectly focused, i.e., blurred, picture. The production of outline pictures is effected by using different modifying signals. If the signals from a differentiating network are rectified, a positive pulse is obtained as the light spot passes over a region of sharp tone gradient. The application of such signals to the intensity control of the monitor results in pictures which show only the contour lines, like line drawings. This process may be used for the production of sketch maps from terrain photographs or for the display of contours on X-ray pictures, etc.

● *PRODUCTION OF HIGH-PURITY MATERIALS BY ZONE MELTING*

The zone-melting technique, originally evolved for the production of germanium crystals of high purity, is now proving useful in other processes. In zone melting a long narrow ingot of impure material is passed slowly through an induction coil, which melts the limited zone of the ingot inside the electric field of the coil. Since impurities are not equally soluble in the liquid and solid phases of the parent substance, the molten zone, as it passes along the ingot, picks up and holds the impurities in solution, thus carrying them to the end of the ingot, where they finally solidify. It need hardly be stressed that the degree to which purification is obtained will depend upon the number of passes, the initial impurity level, the difference in solubility of the impurities in the solid and liquid form, and on the length of the molten zone. An interesting recent application

400 per cent dividend in the first year : as Fibreglass Rigid Sections are **AVAILABLE FROM STOCK** you can start reaping such benefits at once. Write for our booklet now. An uninsulated 3-inch main, 100 feet long, carrying steam at 400°F wastes fuel at the rate of 13.8 pounds every hour—54 tons in a year of 8,000 working hours. Insulated with Fibreglass Rigid Sections, 2-inches thick (with fixing the cost is about £50) the loss is reduced to 4 tons of coal a year — a clear saving of 50 tons — a sheer gain of £200. Fibreglass insulation is paying 400 per cent dividend in the first year.

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now under way is the determination of the reason why Chilean copper is the only copper suitable for use in certain copper-oxide rectifiers. Once the trace impurity responsible for the outstanding suitability of Chilean copper has been found, it may be possible to manufacture a copper with the proper trace elements. Other applications are the production of especially pure tin and antimony. A particularly interesting feature of the process is that it can be reversed to add impurities of closely controlled concentrations, without producing segregation. This method has now entered the practical stage, and may safely be expected to find widespread uses.

● *FLOW FORMING OF METAL PARTS*

A new process for the cold forming of metal parts in the shape of bodies of rotation is claimed to offer a number of important advantages. This new process of "flow forming," as it is called, superficially resembles the well known technique of metal spinning, but differs from it in certain respects. In flow forming, a metal blank is gradually forced to flow under the pressure of a revolving disc against a rotating mandrel, which has the shape desired for the finished part. The mandrel is carried on the lathe spindle, while the revolving disc is carried on the tool slide; the whole operation can be made semi-automatic, merely requiring the operator to load and unload the parts and to stop the machine. One of the distinctive characteristics of the process is that the diameter of the part blank and of the finished workpiece is the same. The thickness of the portions of the part actually formed is reduced, but the end where the part is held and any flange remaining retain the original thickness of the blank. It is claimed that greater uniformity and consistency are obtained with this process than by spinning, as wall thickness can be held to a variation of no more than 0·002 in. Another claim is that tooling costs may be as low as one-tenth those of deep-draw dies. The surface finish produced is said to be excellent. Layout of most parts and determination of blank sizes are relatively simple, because the diameter of the finished part equals that of the blank. It need hardly be pointed out that the application of the process is restricted to symmetrical cylindrical and conical shapes.

● *SHAFT-DISPLACEMENT INDICATOR*

A non-contact type distance gauge for measuring the relative position of a high-speed rotating shaft has been developed. This device incorporates a mutual inductance gauge to indicate the longitudinal movement of the shaft, such as might be caused by the failure or wear of a thrust bearing. This position indicator detects and measures accurately the shaft displacement in either direction. When the displacement exceeds a prescribed limit, the indicator operates an alarm, thereby warning personnel of imminent machine failure. Since the instrument also gives a direct indication of the amount of bearing wear, a turbine bearing supervised in this way may be used for its full useful life and need not be replaced prematurely. In the mutual inductance micrometer which constitutes the sensing element, a transducer probe, consisting of two coaxial, coplanar coils, is mounted on the turbine frame near the shaft. When the primary coil is energised from a radio-frequency source, a voltage is induced in the secondary coil. To the end of the turbine shaft is mounted a brass disc, which forms part of the electrical system, and motion of the disc towards or away from the probe will change the mutual inductance between the two windings. Thus, the output voltage from the secondary winding will depend upon the spacing between the probe face and the brass disc. This voltage is indicated on a meter calibrated in thousandths of an inch, and shows the shaft position relative to the main frame of the turbine. Although the instrument was originally designed to measure longitudinal displacements, it can easily be adapted to measure radial displacements. It can also be applied to indicate the relative position of oscillating or reciprocating machine parts.

● *ENDURANCE LIMIT OF ZIRCONIUM*

In the field of atomic energy, the properties of zirconium and its alloys are of considerable interest to metallurgists and engineers. Although many properties have been investigated thoroughly, little has been known of the fatigue properties of this metal. In a recent test, crystal bar zirconium of $\frac{1}{2}$-in. in diameter was subjected to repeated stress at room temperature in order to find its endurance limit. The fatigue test was carried out in a Krouse repeated-stress machine, using a cantilever beam load applied to the specimen rotating at 8000 rpm. After machining, the specimens were polished longitudinally to a finish of about four micro-inches. The results of these tests showed some variation at the lower values of stress, from which it must be concluded that crystal bar zirconium does not possess a clearly defined endurance limit. Additional efforts to produce zirconium alloys of improved properties appear, therefore, to be indicated.

● *INFLUENCE OF TEMPERATURE AND RATE OF STRAIN ON TORSION STRENGTH*

An experimental study has recently been carried out to determine the effect of temperature and rate of strain on the strength, ductility, and energy-absorbing capacity of a number of structural metals in torsion. These metals include steel, aluminium alloy, magnesium alloy, titanium, and titanium alloy. Cylindrical specimens of $\frac{1}{4}$ in. in diameter were tested at four different constant. strain rates, ranging from 0·00001 in. per in. per second to 12·5 in. per in. per second, and at four

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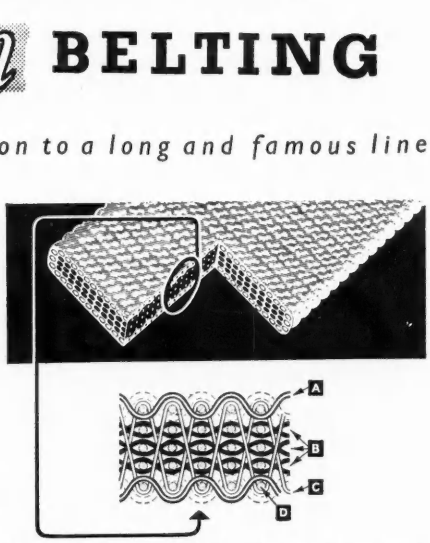

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different temperatures from room temperature to 1200° F. Two series of tests were conducted, in the first of which the specimens were held at the test temperature for thirty minutes before loading; in the second series the specimens were given a 200-hr ageing treatment at the test temperature before testing. Torque, angle of twist, and time were continuously recorded and the torsional properties were determined. In general, it was found that an increase in temperature reduced the strength of all metals except in the blue-brittle range for steel. Extremely high ductility was exhibited by some of the metals at the highest temperatures employed, especially at the slower rates of straining. The 200-hr ageing treatment had no appreciable effect on the properties of most of the metals tested; significant changes were produced only in the aluminium alloys at 400° F and 600° F, and in alloy steel at 1200° F. The experimental observations were compared with several theories which have been proposed to express mathematically the effects of strain rate and temperature on mechanical properties. By proper selection of empirical constants, several equations, involving a general relation for flow stress or new parameters of a "temperature-modified" strain rate or "velocity-modified" temperature, were found to express approximately the variations obtained in mechanical properties.

● *CENTRIFUGAL COMPACTING OF LARGE PARTS*

There is no doubt that in powder-metallurgical technique the production of large parts with uniform properties throughout presents a most difficult problem. Thus, the density of a deep compact formed on an automatic press is considerably higher at the ram face than at the opposite face. While compacts made by hydrostatic pressing are more uniform, they must be shaped or machined, resulting in waste of powder and high labour costs. According to a recent report, most of these drawbacks seem to have been overcome in a new method, known as centrifugal compacting, which is already being employed for the production of tungsten-carbide pieces of 4 lb in weight. In centrifugal compacting, the charged moulds are whirled at speeds approaching 300 mph and the resulting centrifugal force pulls the powder towards the perimeter of the circle of rotation with considerable force. The theory is that, since centrifugal force acts directly on each individual grain of powder, the inter-particle friction, which limits the efficiency of other compacting techniques, is at least partially overcome, and the grains can thus flow more freely in directions angular to the lines of force. However, the pressures achieved in centrifugal compacting cannot, for technical reasons, approach the pressures normally used when pressing tungsten carbide. In fact, pressures produced by the centrifugal effect do not exceed two tons per sq in., whereas normal compacting pressures range from 12 to 15 tons per sq in. In consequence, the compacts produced in the centrifugal process are subject to much greater shrinkage than compacts made by the conventional method, and moulds must be designed accordingly.

● *LEVELLING SURFACES BY ELECTROPLATING*

It is well known that a satisfactory surface finish for stampings, casting, forgings, and fabricated parts cannot be accomplished by bright plating alone. Pleasing, mirror-like finishes call for a very smooth and level surface on the piece to be processed. However, metal polishing and buffing, which once were the standard methods of surface smoothing and levelling, are costly. Moreover, the tools used frequently represent a larger capital investment than the electroplating equipment, and the number of metal polishers required may be five times as large as that of platers. The technique of levelling metal surfaces by electroplating has its origin in the discovery that certain types of plate tend to deposit in depressions and scratches more rapidly than on projection and plateaux. This technique has proved to be more economical than polishing and buffing, and methods have been developed for the use of nickel, copper, zinc, silver, bronze, and speculum alloys as levelling plates. The application of bronze plating as a levelling plate would appear to be especially interesting. Plating of steel with a 20% tin and 80% copper alloy has been found to provide a corrosion-resistant coating which possesses outdoor weathering properties superior to those of conventional nickel plating. A special bath has also recently been developed for depositing iron as an undercoat for nickel. The combined levelling power of the plate is greater than that furnished by the nickel alone. It is claimed that seams, stringers, and other defects in steel surfaces which cannot be concealed by the nickel alone are completely concealed by the combined iron and nickel plating.

● *NEW HARDNESS TEST FOR WIRE*

A recent report points out that the Rockwell hardness test is not recommended for testing the hardness of wire, unless the specimen is ground with parallel sides, and unless it is confined to wire of such diameters that no bulging of the specimen can occur under test. Consequently, for circular wire the tensile-strength test is considered preferable to the Rockwell hardness test. A novel hardness test for wire has now been devised, which is claimed to be simple and accurate and which can be carried out with all machines used for Rockwell hardness testing. It can be applied to wire of from 0·005 to 0·125 in. in diameter for the measurement of hardnesses ranging from that of aluminium to that of tungsten carbide. The new method depends on the use

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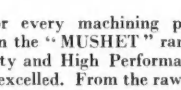

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of wedge-shaped diamond indenters, which give approximately elliptical impressions, in contrast to the square impressions of the Vickers test and the round impressions of the Brinell test. The wedge-shaped diamond used for the 60-kg load has an included angle of 120 deg. and an 0·008-in. radius. Conversion of wedge values to Rockwell values was found to be a highly complex matter, because the penetration, as measured by the Rockwell test, is not really the fundamental factor, hardness being determined by the area of the impression made by a definite load. When variation of depth of penetration produces geometrically similar projected impressions, as in the Vickers or Rockwell test on flat stock, then penetration can be converted to hardness. With the diamond-wedge penetrator, variations in depth of penetration do not produce similar impressions, because the major axis of the ellipse produced varies with the wire diameter.

● *PROXIMITY PICK-UP IMPULSE GENERATOR*

A new proximity pick-up generator incorporates a high-frequency carrier-operated transducer and works on a principle similar to that employed in military mine detectors. With suitable auxiliary equipment, this device may be used to indicate mechanical or electrical counting, linear or angular position, rate of travel, sequence timing, vibration frequency, angular or linear speed, or other functions which involve moving metal components. This new pick-up system consists of a transducer connected by a ten-foot cable to a control unit containing the power supply and other electronic components. It produces a d.c. voltage of constant amplitude when any metallic mass is brought near the pick-up. No mechanical contact is made with the exciting metal. The d.c. voltage remains constant as long as the exciting metal is in close proximity to the pick-up, and drops to zero when it is removed. The rise and delay time of the voltage is rapid, thereby producing a definite snap action. It produces a constant output voltage which is independent of either the speed of the actuating mass or the pick-up spacing, and it will operate at any speed from 0 to over 12,000 times per minute.

● *MANUFACTURE OF PRINTED CIRCUITS*

The manufacture of printed circuits is known to involve the problem of obtaining a uniform bond between the copper sheet and the base. This problem can be solved only by cleaning the copper sheet before the adhesive is applied, and by ensuring the unvarying reliability of the adhesive employed. A recent improvement in the process is due to the development of a new synthetic elastomer with a thermosetting resin. This has made it possible to provide the user with copper sheets cut to the proper size and pre-coated with the adhesive. Application of the copper sheet to the base is then effected by placing the adhesive-coated copper sheet on the impregnated paper or previously formed laminate, and then carrying out curing and final lamination in a heated press. In the next process stage, appropriate portions of the copper layer are etched away, so as to leave the printed circuit on one or both sides of the base board. The latter is subsequently dipped into a bath of molten solder at a temperature ranging from 390 to 450° F, with the result that molten solder adheres only to the copper lines which have remained on the board after etching. The base board may be of phenolic resin, which has higher strength than silicone, but has a lower heat resistance than either silicone or epoxy. Silicone has a far higher heat resistance than either phenolics or epoxy, but its structural strength is less and its cost is higher. The polished electrolytic copper sheet is usually of one-ounce or two-ounce per sq ft gauge.

● *FINISHING OF METAL-POWDER PARTS*

While many metal-powder parts require no finishing, there are many which require finishing either for protection or for decorative purposes. Unfortunately, metal-powder parts cannot be finished with the standard procedures of cleaning, plating, oxidising, blackening, phosphatising, or any other type of aqueous-solution treatment. This shortcoming is due to such factors as surface and internal porosity, powder composition, effects of sintering, etc. Among these, porosity is outstanding in importance, and several processes are now available for sealing the pores effectively. One such process employs sodium silicate, with or without a filler consisting of a very fine metal powder. With metal-powder fillers, however, there is a risk that particles will filter out of solution and bridge microscopic pores, which eventually may rupture under wear and may unseal a capillary duct. Recently, plastic compounds which are air setting and require no baking have come to the fore. The best impregnants are those of low viscosity and preferably of low volatility, which dry or cure to solid infusible materials, with little or no loss in volume. Among the various impregnating methods available, the internal-pressure method and vacuum impregnation are often preferred. In the internal-pressure method, the surface is sealed, except for a single port, into which impregnant is introduced under pressure. This method is, however, expensive and leaves air in microscopic holes. This drawback is eliminated in a vacuum process in which all ports are sealed, with a vacuum connection at one port. The compact is submerged in the sealing compound and is vacuum-drawn to pull the sealing medium through the walls from outside to inside. Suitable impregnants are sodium silicate, styrene, tung oil, linseed oil, phenolic resin, etc.

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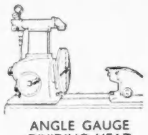

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